AIR QUALITY ASSESSMENT STUDIES IN THE WAWA AREA 1975

Ministry of the Environment
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Air Quality Assessment Studies

In the Wawa Area, 1975

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ONTARIO MINISTRY OF THE ENVIRONMENT
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I INTRODUCTION:

The Ontario Ministry of the Environment conducted a number of studies in the Wawa area during 1975 to assess the effects of the emissions of the Algoma Ore Division, Algoma Steel Corporation Ltd. sinter plant on the local environment. Many of these studies have been ongoing for several years while others were initiated in 1975. The studies can be divided into 5 distinct categories.

a) Air monitoring
b) Vegetation injury surveillance
c) Vegetation and soil sampling for chemical analysis
d) Vegetation study plots
e) Snow sampling for chemical analysis

Two continuous sulphur dioxide monitors were operated in the Wawa area during 1975. The monitor at Goudreau was operated from mid May until the end of September while the monitor at 29 Hillcrest Ave. has been operated continuously since mid May of 1975. Continuous SO_2 monitors have been operated at both these locations during the past several growing seasons (May - October). Lead peroxide candles were exposed at 10 locations in the area during 1975 and were exchanged monthly (May - October). One high volume air sampler has been in operation in the Town of Wawa since June, 1975. The locations of the Wawa area air monitoring sites are shown in Figures 1 and 5.

Monthly vegetation surveillance studies were conducted in the Wawa area to document the degree and extent of vegetation injury by sulphur dioxide and other agents. A number of complaints of vegetation injury by SO_2 were received and investigated by the Ministry.

Samples of vegetation and soil were collected for chemical analysis at a number of sites in the Wawa area during 1975. This sampling program commenced in 1969 and has been expanded and modified since its inception.

An additional vegetation study plot was set up in 1975, bringing the total to 10. This program also began in 1969 and has been continued with certain modifications since that date. Monthly visits were made to the vegetation study plots (May to October) and notes made regarding the condition of the tagged trees and shrubs on the plots and the condition of the vegetation in the area surrounding the plots. The locations of the plots are shown in Figure 1.

In order to better assess the short term effects of additions of sulphur and metals to the environment fresh snow samples were collected for chemical analysis during January of 1975. Snow samples were collected at 17 locations in the area mainly to the northeast and southwest of the sinter plant and at one control location. The locations of the snow sampling sites are shown in Figure 8.

II SULPHUR DIOXIDE CONCENTRATIONS IN THE WAWA AREA DURING 1975:

A) Production and Emission Data:

The Algoma Ore Division iron ore deposits in the Wawa area vary in their sulphur content. The Company, in an effort to limit sulphur dioxide emissions and the resultant acute vegetation injury began a program in 1961 whereby the lower sulphur content ores are processed during

the growing season (mid-May to mid-September) and the higher sulphur content ores during the non-growing season. The program has been continued with a measure of success during the growing seasons of 1961 to 1975. The effectiveness of the program is difficult to assess as vegetation injury by sulphur dioxide is influenced by a number of factors other than the actual concentration of sulphur dioxide and the time of exposure. Meteorlogical conditions, plant growth rate and stage of maturity of the plant are three such factors. However, it is probable that acute vegetation injury by sulphur dioxide would have been more frequent and more severe in the Wawa area during the past growing seasons had the program not been in effect.

In Table 1, the production and emission data for the period May 1st. to September 30th., 1975 are presented. The relationships between ore feed, sinter production and sulphur content of the ore feed are illustrated in Figure 2.

The raw ore feed ranged from a high of 242,954 gross tons in July to a low of 199,750 gross tons in September and the five month average was 214,626 gross tons. The ore feed for the five month period was 1,073,132 gross tons.

The average sulphur content of the ore was 3.22%. The sulphur content ranged from a low of 2.55% in September to a high of 3.88% in May.

A total of 34,083 gross tons of sulphur were emitted to the atmosphere from the sinter plant during the five month period. Sulphur emissions were lowest in September (4,991 G.T.) and highest in July (8,174 G.T.).

In the Table below, production and emissions data for the period of June 1st. to September 30th. for the 1975 season are compared to similar periods for the 1973 and 1974 seasons.

Season	Ore Feed (G.T.)	Sinter Production (G.T.)	Sulphur Emitted (G.T.)
1975	867,815	561,614	26,211
1974	1,058,773	664,744	31,697
1973	1,031,408	677,702	33,051

Ore feed was 19% less in 1975 than in 1974 and 16% less than in 1973 for the same time period (June 1st. to September 30th.)

Sinter production was 16% less in 1975 than in 1974 and 16% below the 1973 production level.

Seventeen percent less sulphur was emitted during the period June 1st. to September 30th., 1975 than the same period during 1974 and 21% less than during the same period for 1973.

B) Sulphur Dioxide Data Recorded in the Town of Wawa During 1975:

Ground level concentrations of sulphur dioxide were monitored by the Ontario Ministry of the Environment at 29 Hillcrest Avenue, Wawa

during 1975. The recorder was set up on May 21st. and has been running with a high degree of efficiency since this date. With the exception of August, when equipment breakdowns were common, the monitor has been recording valid data over 95% of the total time period. The 1975 season was the seventh season that the emissions of the Algoma Ore Division, Algoma Steel Corporation Ltd. have been monitored at the Hillcrest Avenue station. Since the main purpose of this report is to describe the effects of SO_2 on vegetation, only the data pertaining to the growing season (May to October) are presented.

In Table 2, the SO_2 data collected at Hillcrest Avenue, Wawa during May to October, 1975 are presented.

During May, 1975, some level of SO_2 was recorded during 141 hours. The maximum one-hour concentration during the 11 days of operation was 0.25 ppm.

Valid data were collected 100% of the time during June, 1975. One hundred and eighty-eight hours of SO_2 were recorded (26% of the sampling time), and the maximum one-hour concentration was 0.22 ppm.

Only 38 hours of SO_2 were recorded during the entire month of July, however, more than one-quarter of the 38 SO_2 readings were over 1.00 ppm and the maximum one-hour concentration was 2.13 ppm. This is the highest one-hour concentration recorded at this station in the seven seasons of operation. The ten one-hour concentrations in excess of 1.00 ppm were part of a fumigation which began at 7:00 pm on July 24th. and ended at 3:00 pm on July 25th. The fumigation caused severe injury to vegetation on a number of properties in Wawa. It has been observed in the past that vegetation is often injured by SO_2 when the following concentrations are reached or exceeded for the following time periods during daylight hours during the growing season. An intensity factor of 100 has been assigned to any one of the following combinations and any fumigation with a calculated intensity equal to or greater than 100 is termed a potentially injurious fumigation.

0.95 ppm for 1 hour
or 0.55 ppm for 2 hours
or 0.35 ppm for 4 hours
or 0.25 ppm for 8 hours

Any of the above combinations could cause acute injury to vegetation. The maximum average one-hour concentration was 2.13 ppm. The calculated intensity of this fumigation was 400, 4 times the level which is considered to be potentially injurious to vegetation.

Equipment breakdowns occurred frequently during August and valid data were collected only during 11 days of the month. Seven hours of SO_2 were recorded during the 11 days of operation and the maximum one-hour concentration was 0.03 ppm. While the data for 20 days in August could not be validated, the monitor was operational and it appears that there was only one major fumigation during this period and that was a four-hour fumigation on August 15th. The concentration of SO_2 during this fumigation could not be calculated accurately, however no acute vegetation injury was observed on plant species which are sensitive to SO_2. Therefore the intensity of the fumigation was presumed to be less than 100.

Sulphur dioxide was recorded during 32% of the sampling time during September. Thirty percent of the 40 SO_2 readings were above 0.25 ppm, 8% above 0.50 ppm and 1% above 1.00 ppm. The maximum one-hour concentration was 1.18 ppm. Two potentially injurious fumigations were recorded during the month, one on September 12th. with an intensity of 123 and one on September 26th. with an intensity of 172.

In October, 32 hours of SO_2 were recorded. Ten hours were above 0.25 ppm, 5 hours above 0.50 ppm and 2 hours above 1.00 ppm. The maximum one-hour concentration was 1.35 ppm and this occurred on October 15th. The intensity of this fumigation was 104.

During the 1975 season the monitor was operated for 3,360 hours. Of this total 446 (13%) were SO_2 readings and the remainder were zero readings. Nine percent of the SO_2 readings were above 0.25 ppm, 5% above 0.50 ppm and 3% above 1.00 ppm. The maximum one-hour reading was 2.13 ppm. A concentration of SO_2 in excess of 1.00 ppm was recorded during the months of July, September and October of 1975.

In Table 3, the data collected at Hillcrest Avenue, Wawa during the past four seasons are summarized. Only the data pertaining to the months of June, July, August and September are included in this Table since the monitor was not operational for the months of May and October during all four seasons. Vegetation injury by SO_2 has been observed in the Wawa area only during the months of May through September in past seasons. There are considerable variations in the data from month to month and season to season mainly as a result of changing meteorlogical conditions and variations in the sinter plant emissions.

The total sampling time during the four months of 1975 was less than during the same period for the three previous seasons because of the fact that the monitor was operated for only 226 hours during August of 1975. During the 1973 and 1974 seasons the sampling time was over 95% of the total period. Invalid datawere common during June and September of 1972 resulting in the second lowest sampling time during the past four seasons.

Some level of SO_2 was recorded 11% of the sampling time at Wawa during 1975. The frequency of SO_2 was considerably less during 1975 than in 1973 and 1974 but more than in 1972.

The maximum SO_2 concentrations for the 1972 and 1973 seasons are ½ hour concentrations while those for the 1974 and 1975 seasons are one-hour concentrations. A Thomas autometer was the instrument operated at Wawa during 1972 and 1973 while a Davis instrument was used during 1974 and 1975. The former instrument reported ½ hour average concentrations while the Davis instrument reported one-hour concentrations. On July 25th., 1975, a one-hour concentration of 2.13 ppm was recorded at Wawa and this is the highest concentration ever recorded at this station.

Three potentially injurious fumigations were recorded at Wawa during 1973, 1974 and 1975. No such fumigations were recorded during the four month period of 1972. Seven of the total of nine potentially

injurious fumigations recorded during the past three seasons occurred in September. Changes in wind direction during September are probably responsible for the high frequency of these fumigations during this month.

The average concentration of SO_2 for the total sampling period during 1975 was about the same as the three previous seasons. The average concentration for sulpur dioxide periods only was higher in 1975 than in the three previous seasons. The reason for this high level (0.12 ppm) is that fumigations with abnormally high levels of SO_2 occurred at Wawa during July and September of 1975.

C. Sulphur Dioxide Data Recorded at Goudreau During 1975:

One continuous SO_2 monitor was operated at Goudreau, 35 km northeast of Wawa by the Ontario Ministry of the Environment from May 21st. to September 30th., 1975. Valid data were collected over 85% of this period. A continuous monitor has been operated at Goudreau each growing season since 1961.

In Table 4, the data collected at Goudreau during 1975 are summarized and in Table 5 the 1975 data are compared to data from the 1972, 1973 and 1974 seasons.

The recorder was started for the season on May 21st. During the 11 days of sampling during May, some level of SO_2 was recorded approximately 27% of the time. The maximum one-hour concentration was 0.25 ppm and there were no potentially injurious fumigations.

Valid data were collected for 100% of the total time during June. Sulphur dioxide was recorded for 33% of the sampling time. There was one hour with a concentration in excess of 0.25 ppm and the maximum one-hour concentration for the month was 0.35 ppm. The maximum intensity of any fumigation recorded during the month was 33 and this occurred on June 2, 1975.

Valid data were collected 99% of the total time during July. Sulphur dioxide was recorded 63% of the time, however there was only one hour above the 0.25 ppm level. The maximum one-hour concentration was .32 ppm. Forty was the maximum intensity of any fumigation recorded during the month.

During August, valid data were collected 99% of the time. Some level of SO_2 was recorded during 118 hours during the month. Nine hours were in excess of 0.25 ppm and the maximum one-hour concentration was 0.40 ppm. The fumigation with the highest intensity of all the fumigations recorded for the season, 76, was recorded on August 16th., 1975.

Equipment breakdowns and power failures were common at Goudreau during September. As a result, valid data were collected only 35% of the time during the month. One hundred and fifty-one hours of SO_2 were recorded during the 253 hours of sampling during the month. The maximum one-hour concentration was 0.25 ppm and the maximum intensity was only 16.

During the growing seasons of 1972 to 1975 the recorder at Goudreau was operated for only part of May and October. In order to

more accurately compare the data from the previous seasons to that of 1975 the data from only June through September are compared in Table 5.

The total sampling time during the four months of 1975 was about the same as in 1972 and 1973 but considerably greater than in 1974. The variation in sampling time from month to month and season to season is due to equipment breakdowns and power failures.

More hours of SO_2 (973) were recorded during 1975 than any of the three previous seasons. The least number of hours of SO_2, 494, were recorded during the 1973 season. The variation in the number of hours recorded during the various months and seasons is due to a number of factors, such as variation in SO_2 emissions, meteorological conditions and differences in the amount of time the monitor was inoperative.

The maximum one-hour SO_2 concentrations for the 1975 and 1974 seasons were 0.40 ppm and 0.87 ppm respectively. The SO_2 data recorded at Goudreau during the 1973 and 1972 seasons were in one-half-hour concentrations. The maximum one-half-hour concentration for the 1973 season was 0.97 ppm while the maximum concentration for the 1972 season was 0.32 ppm.

Only two potentially injurious fumigations have been recorded during the past four seasons at Goudreau. One with an intensity of 118 was recorded on July 29th., 1973 and another with an intensity of 109 on July 27th., 1974. The average concentration in ppm for SO_2 periods only was the highest during the 1973 season (0.07). The average ranged from a high of 0.09 ppm in September of 1973 to a low of 0.01 ppm in September of 1972. The average concentration in ppm for total sampling periods did not exceed 0.03 ppm for any month during the four seasons.

D. Lead Peroxide Candle Survey:

During the 1975 growing season a total of ten lead peroxide candles were exposed in the Wawa area for the purpose of monitoring sulphation rates in the ambient air. The candles were located adjacent to the vegetation study plots as illustrated in Figure 1. The candles at plots #1 and #2 were installed in 1975 and 1974 respectively, whereas the other candles were originally set out in 1970. The candles were exchanged approximately every 30 days and subsequently analyzed for sulphur trioxide . The sulphation rate is expressed as the number of milligrams of sulphur trioxide per 100 cm^2 of exposed candle area per day, based on a 30 day average.

The results of the candle survey are shown in Table 6 of the appendix. The sulphation rates during June, July, August and September of 1975 are compared to the average for the same period of time for the 1970 to 1974 seasons. The candles at locations 56 km NW and 61 km NE are sufficiently removed from the sinter plant that the sulphation rates can be considered as background levels. From Table 6 it is observed that the sulphation rates at these locations are 0.06 and 0.04 mgm SO_3/100 cm^2/day, ie: about one order of magnitude lower than at the other locations.

During the 1975 growing season the O.M.E. criterion of 0.70 mgm SO_3/100 cm^2/day was exceeded a total of 9 times at the candle locations

within the fume damage area as indicated in the Table below. The majority of these excessive levels were recorded at locations 12 and 16 km NE of the sinter plant. At these locations very high levels of sulphation were recorded for the period mid June to mid July. The levels then were 2.15 and 2.57 mgm SO_3/100 cm^2/day respectively.

Location in Relation to the Sinter Plant	Maximum Sulphation Rate Reading (mgm SO_3/100 cm^2/day)	Number of Times Above O.M.E. Criterion	Relation to the 1970-1974 Mean
1.6 km SW	0.20	Nil	--
12 km NE	2.15*	3	--
16 km NE	2.57*	3	Higher
19 km NE	1.66	2	Same
26 km NE	0.79	1	Higher
30 km NE	0.58	Nil	Lower
35 km NE	0.48	Nil	Higher
38 km NE	0.63	Nil	Higher
61 km NE	0.09	Nil	Lower
56 km NW	0.05	Nil	Same

* Mid June to Mid July

Over the past several years sulphation rates as low as 0.40 mgm SO_3/100 cm^2/day have been related to acute SO_2 vegetation injury in the Wawa area. During the 1975 growing season this level was exceeded a total of 18 times representing approximately 50% of the total number of readings for that period of time. This represents a substantial increase over the 1974 season when the 0.40 level was exceeded on 10 occasions.

The mean sulphation rates during 1975 for the candles were compared to the multi-year means. Of these 29 total sulphation rates for 1975, 10 were higher than the corresponding means, 3 were the same and 16 were lower. The average sulphation rate for the period mid June to mid July was significantly higher than that of the other months. For that period, most candles recorded their highest sulphation rates for the 1975 growing season.

The relationship between the percent sulphur content in vegetation samples collected near the candle locations and the rate of sulphation on the lead peroxide candles at these locations is shown in Table 6. and in Figures 3 and 4 for the 1974 and 1975 seasons.

The 8 sites located northeast from the sinter plant and lying within the fume damage area were chosen for this analysis. The sulphation rates are the seasonal means for the growing seasons for each year.

The sulphur content of the vegetation (white birch) is the mean for all samples collected in June, July and August for 1974 and July and August for 1975. Figures 3 and 4 indicate that the correlation between these parameters, ie: sulphation rate and % sulphur in vegetation, is fairly high with correlation coefficients of 0.89 and 0.93 in 1974 and 1975 respectively. Similar relationships between sulphation rate and sulphur content in vegetation have been observed in the past several years in the area to the northeast of Wawa where most of the vegetation injury from sulphur dioxide has occurred.

III VEGETATION INJURY IN THE WAWA AREA DURING 1975:

A. Injury by Sulphur Dioxide:

Vegetation injury by SO_2 to the northeast of Wawa was less common and less severe during 1975 than in previous seasons. However, some degree of injury was noted on a number of plant species during June, July and August.

By mid June, trace (1-5% of leaf area affected) to light (6-15% of leaf area affected) injury was evident on white birch and red raspberry at plot #3. Light to moderate (16-35% of leaf area affected) SO_2 injury was evident on trembling aspen, and white birch at plot #2 at this time. At plots #4 and #5, typical SO_2 injury symptoms were evident on bracken fern, white birch, blueberry and red raspberry. The injury on these plant species was trace to light in nature. The maximum distance to the northeast at which SO_2 injury occurred in June was approximately 20 kilometres. No SO_2 injury was observed on any plant species in the Town of Wawa or in any direction other than northeast from the sinter plant during June.

During the July surveillance (July 14th. to July 17th.) SO_2 injury was noted on white birch and red raspberry in the vicinity of plot #3. This injury was severe in nature (over 35% of the leaf area affected). At plot #4 severe SO_2 injury was evident on trembling aspen and white birch, bracken fern and showy mountain ash. This injury was recent, probably occurring a week or so prior to the surveillance. Recent severe SO_2 occurred on white birch and trembling aspen during July at plot #2.

Severe sulphur dioxide fume damage occurred on vegetation following a 20 hour fumigation on July 24th. and 25th., 1975. The fumigation began on the 24th. at 7:00 pm and ended at 3:00 pm on the 25th. The average SO_2 concentration during the fumigation was 0.89 ppm and the maximum hourly concentration was 2.13 pppm. The intensity of the fumigation was calculated to be 400, four times the level generally considered capable of causing visible SO_2 injury on vegetation.

The approximate area over which visible injury to vegetation occurred is shown in Figure 5.

The tree species which was the most severely injured was white birch, however, varying degrees of injury occurred on white pine, jack pine, red pine, trembling aspen, larch, showy mountain ash, manitoba maple, dogwood and balsam poplar. Injury also occurred on a wide variety of vegetables and flowers.

The Ontario Ministry of the Environment received complaints from 27 residents concerning vegetation injury resulting from this fumigation. Ministry personnel investigated the complaints and furnished each of the complainants with a written report, describing the degree and extent of vegetation injury by SO_2. No requests were received from the complainants for assistance from the Board of Negotation in mediating financial settlements of the claims.

During the August surveillance (August 18th. to 21st.) severe SO_2 injury was observed on white birch trees in the vicinity of plot #2. This was the only recent SO_2 injury observed during the August visit.

B. Injury by Other Agents:

During the monthly surveillance visits, vegetation injury by agents other than SO_2 was observed in the Wawa area.

The 1975 season was the first season that severe drought injury occurred on trees and shrubs in the area. The drought injury was evident in July and became more common and severe during August. The injury was widespread throughout the area and tended to be more severe on trees growing in areas where the soil was shallow, especially on slopes and ridges. The drought injury made it impossible to map fume damage boundaries from the air. The severe drought reduced the degree and extent of acute SO_2 injury.

Some degree of vegetation injury was caused by numerous types of insects in the Wawa area during 1975. Spruce budworm injury was common on spruce and balsam fir and leaf miner injury was common on white birch trees in the area.

Vegetation injury, incited by such biological agents as fungi and mites was observed at a number of locations in the Wawa area during 1975.

IV WAWA VEGETATION STUDY PLOTS:

A. Program Outline:

In 1969 six permanent vegetation study plots were established in the area northeast of Wawa where acute sulphur dioxide injury had been observed on vegetation in previous years. Two control plots were established outside the fume damage area. In 1974 a ninth plot was established at Lucy Pit (10 km northeast of the sinter plant) and the plots at Herman Lake and Crouche were relocated. In 1975 an additional plot was set up 1.6 km southwest of the sinter plant. The locations of the 10 plots are listed below and marked on the map in Figure 1.

Plot No.	Distance and Direction from the Algoma Ore Division Sinter Plant	Location
1	1.6 km SW	Magpie River
2	10 km NE	Lucy Pit
3	16 km NE	Parks Lake
4	19 km NE	Finger Lake
5	26 km NE	Perry Lake
6	30 km NE	Garbe Lake
7	35 km NE	Goudreau
8	40 km NE	Troupe Lake
9(control plot)	45 km NE	Dubreuil Road
10(control plot)	56 km NW	Obatanga Park

At the time of the plot establishment 10 trees (white birch and/or trembling aspen) were selected and tagged over an area of 20 metres by 20 metres. Ten shrubs (mountain maple, mountain ash, prairie willow, dogwood, pin cherry, speckled alder, beaked hazel or serviceberry) were also tagged over the same area at each location. The heights and diameters of all tagged individuals as well as the general condition of the individuals were recorded. Monthly surveillance visits have been made to each plot during the growing seasons since plot establishment. The incidence of SO_2 injury, insect injury and the general condition of the tagged individuals has been recorded each month of the growing season (May to October) since the plots were established.

Two permanent metre square grids were set up at the original 8 plots in 1969. Each August, 1969 to 1973, the grids were examined and the number of plant species and individual plants were tabulated. In 1974 and 1975 the grid program was altered and during these seasons a number of randomly assorted grids (not permanent) were examined at each plot.

Vegetation and soil samples for chemical analysis have been collected in the vicinity of each plot during each growing season since the plots have been established.

B. Tree Crown Conditions:

During June, July and August of each year, the tagged trees and shrubs on the Wawa area vegetation study plots have been rated according to a crown classification system developed by the Canadian Forestry Service. Under this system a healthy tree or shrub would be rated 1A; an individual in the state of some decline, 1B, 2A or 2B; a specimen in the state of moderate decline, 3A, 3B, 4A or 4B; one in a state of severe decline, 5A or 5B; and a dead specimen, 6A. In assessing the crown conditions, such factors as SO_2 injury, insect and disease injury, mechanical injury and drought have been considered.

In Table 7 the crown conditions of the tagged individual in August of 1975 are compared to the conditions in August of 1974. The figures for the 1974 season are based on 180 specimens and the 1975 figures on 200 specimens. The major change from 1974 to 1975 was the increase in the "some decline" category (1B, 2A or 2B). This was caused mainly by drought injury at plots 6, 7 and 8. The soil profiles at these plots are shallow and the trees and shrubs were adversely affected by the abnormally low rainfall during July and August of 1975. There was a decrease in the number of trees and shrubs in the "moderate decline" category in 1975 from 1974. This was due to severe sulphur dioxide and insect injury at plots 3, 5, 6, and 7 during 1974.

In Table 8 the changes in the crown conditons of the tagged specimens from date of establishment until August of 1975 are summarized. Eighty-five individuals remained constant, 27 improved and fifty-eight declined. In general the rate of decline was greater in the plots closer to the sinter plant than the distant plots. Although sulphur dioxide is largely responsible for crown condition decline, especially at plots # 2, 3 and 4, these declines cannot be attributed entirely to the effects of sinter plant emissions as other factors such

as condition of the individual when first tagged, insect and disease injury, mechanical injury, browsing and physiological injury are also partly the cause of the declines. The individuals which were tagged in 1974 in most cases remained in a constant condition.

C. Plant Population Studies:

In Table 9, the data from this study are summarized. The number of trees, shrubs and herbaceous plant species and the percent cover for each, and for the total are shown in this Table.

These data show that the total number of plant species did not change significantly with distance from the sinter plant; the relative percentage of tree cover to herbaceous plant cover and the number of tree species increased with increased distance from the source. At plots #2 and #3 (10 km and 16 km NE of the source) only white birch and trembling aspen were found, and total tree coverage was only 12%. Because of the lack of tree cover, herbaceous plants at plots #2 and #3 were plentiful accounting for 104% and 161% respectively. The tree canopy became more dense with increased distance from the sinter plant and herbaceous plant coverage declined.

An analysis of the plant species found at each of the plots indicate that three species were found exclusively in the control area, Picea mariana (black spruce), Chamaedaphne calyculata (leather leaf), and Lycopodium lucidulum. Only one species was found exclusively at plot #2, Aralia racemosa (spikenard); and except for a group of weedy species, two species were found exclusively at plots #2 and #3, Sambucus pubens (red berried elder), and Polygonum cilinode (bindweed).

There did not appear to be any significant trends regarding the amount of bare ground or dead wood on the ground from plot to plot.

D. Chemical Analysis of Vegetation and Soil Samples:

In 1969, a progam of sampling vegetation and soil at a number of locations in the Wawa area was initiated. The program has been continued each year since 1969 with a number of modifications. In the first 6 years the program was in effect foliar samples of two trees and two shrubs, and soil (0-10 cm) were collected during June, July and August and analyzed for iron, zinc, arsenic and sulphur. In 1975 only white birch leaves and soil were collected at 10 locations in the area during July and August. Triplicate leaf and soil samples were collected during both months at each location.

In Table 10, the concentrations of iron, arsenic and sulphur in the leaf and soil samples collected during 1975 are presented. Unless indicated otherwise the concentrations in this Table are the average of triplicate sample analysis.

The concentrations of iron (ppm) were highest in the vegetation and soil samples collected at plot #1 (1.6 km SW of sinter plant) and tended to decrease with increased distance from the source. The average concentration in the six vegetation samples collected at plot #1 was 1253 ppm while the average iron concentrations in samples from the two

control locations were 158 ppm and 66 ppm. The average iron concentration in the six soil samples collected at plot #1 was 2.46%. There was considerable variation in the iron levels from month to month and from plot to plot. However, despite the fact that iron is present in high concentrations in the natural soils of the Wawa area, emissions of iron from the sinter plant have resulted in elevated levels of iron in the vegetation and soil at the sampling locations close to the sinter plant.

The percent total sulphur in white birch samples ranged from a high of 0.66% in August at plot #1 to a low of 0.09% at plot #10 in July. In general the % sulphur in the white birch samples was highest at the plots closest to the source and in most cases was higher in the samples collected in August than those collected in July. There was considerable variation in the % sulphur in the soil samples collected at the plots in 1975. There were no definite trends regarding distance from the source or from month to month in the concentrations of total sulphur in the 1975 soil samples.

In Tables 11-13, the levels of iron, arsenic and total sulphur in foliar samples of white birch and soil (0-10 cm) in samples collected during 1971-1975 are presented.

The iron concentrations in soil varied from a high of 3.52% at plot #4 in 1971 to a low of 0.04% at plot #10 in 1975. There was variation in the iron levels in the soil samples from year to year and this was probably due to natural variations in the soil iron levels in the Wawa area. The iron concentrations in leaf samples tended to be more uniform from season to season and in all cases were lower at the control locations than at the plots close to the source.

The arsenic concentrations in the soil samples collected over the past 5 seasons tended to be fairly uniform from season to season at all plots. The highest arsenic concentration, 92.0 ppm was found in the soil samples collected at plot #1 during 1975. During the past five seasons arsenic concentrations in vegetation have been consistently higher at the plots #1, 2, 3 and 4 than at the other plots. Foliar samples of white birch tended to be elevated in arsenic content at plots which had elevated concentrations of arsenic in the soil.

There did not appear to be any trends in the % sulphur in the soil samples collected over the past five years. The % sulphur in the vegetation samples decreased with increased distance from the sinter plant.

E. Arsenic Soil Survey:

A special study to investigate arsenic emissions from the iron sinter plant in Wawa was completed in September - October, 1975. Triplicate soil samples were taken at three depths (0-5 cm, 5-10 cm and 10-15 cm) at 24 sites in the Wawa area. The sites included the 10 vegetation study plots, sites between Wawa and Michipicoten Harbour and a number of locations to the northeast of the sinter plant. The sampling locations are shown in Figure 7 and include the following:

1	Government Road, Wawa	0.5 km SE
2	Site 7	1.1 km N
3	Site 6	2.2 km NE
4	Site 5	4.2 km NE
5	Site 4	6.3 km NE
6	Site 3	7.7 km NE
7	Site 2	10.8 km NE
8	Site 1	13.8 km NE
9	Parks Lake	16 km NE
10	Finger Lake	19 km NE
11	Perry Lake	26 km NE
12	Garbe Lake	30 km NE
13	Goudreau	35 km NE
14	Troupe	40 km NE
15	Lucie Pit	12 km NE
16	Wawa Park	1.6 km SE
17	Highway # 17	1.6 km SW
18	Obatanga Park	56 km NW
19	Dubreuilville Road	45 km NE
20	Beck Public School	2.2 km SE
21	Hawk Junction	21 km E
22	Centennial Park	1.7 km SSE
23	Mission Road	8.0 km SSW
24	Michipicoten Harbour	9.0 km SW

The samples were analyzed for the arsenic, sulphur, iron, copper, zinc, manganese, calcium and magnesium content. At the time of the writing of this report only the arsenic results were available and these are presented in Table 14.

RESULTS:

The arsenic concentrations in the 0-5 cm portion of the soil profile were in all cases higher than the 5-10 cm or the 10-15 cm portions of the profile at all sampling sites. The highest concentration (728.0 ppm) was in the sample collected at Government Road in the Town of Wawa. The concentrations of arsenic in the other 3 sample sites in the town were:

Beck Public School - 14.4 ppm; Centennial Park - 35.0 ppm; and Wawa Park - 38.2 ppm. The arsenic concentration in the 0-5 cm part

of the soil profile at the sample sites northeast of the plant was highest at site #6 (2.2 km NE) and decreased with increased distance from the plant. The arsenic levels in the upper portion of the profile at the two control sites were 2.8 ppm and 0.4 ppm.

The arsenic concentrations in the 5-10 cm part of the profile were higher than the 10-15 cm portion of the profile at 19 out of 23 of the sites. The highest level in this part of the profile was 97.5 ppm at site #6. The 5-10 cm portion of the profile of the 4 sampling sites in the town were as follows:

Beck Public School - 2.7 ppm; Centennial Park - 5.1 ppm; Government Road - 75.4 ppm; and Wawa Park - 8.8 ppm. There was a decrease in the arsenic concentrations in this portion of the profile with increased distance from the plant. Control samples had 1.1 ppm and 0.3 ppm of arsenic in this portion of soil profile.

The arsenic concentrations in the 10-15 cm part of the profile ranged from a high of 86.1 at site #6 to a low of 0.3 ppm at Obatanga Park. This part of the profile had the following concentrations at the sample sites in the town:

Beck Public School - 4.1 ppm; Centennial Park - 8.2 ppm; Government Road - 15.2 ppm and Wawa Park - 6.7 ppm.

Since the arsenic levels in the 0.5 cm portion of the soil profile were substantially higher at sampling sites close to the sinter plant and decreased with increased distance from the plant, it can be concluded that the emissions of the sinter plant have, over the years, caused a build-up of arsenic in the soils near the plant. The fact that the concentrations of arsenic in the 5-10 cm and the 10-15 cm parts of the profile were considerably lower than the upper portion of the profile supports this conclusion.

V. RESULTS OF HIGH VOLUME SURVEY:

In June, 1975, a high volume air sampler was installed on the property of the Great Lakes Power Company at the intersection of Churchill Avenue and Mission Road in the Town of Wawa for the purpose of monitoring particulate emissions from the Algoma Ore Division sinter plant. A second high volume sampler will be installed on Hillcrest Avenue, Wawa in March, 1976. The locations of the ambient air quality monitoring sites are shown in Figure 5.

The high volume air sampler determines the concentration of suspended particulate matter in the air ie: the solid particulate matter that either takes a very long time to settle to the ground or does not settle at all owing to its very small mass. This instrument draws approximately 1.5 cubic metres of air per minute through a preweighed filter medium.

The increase in weight of the filter then determines the amount of suspended particulates deposited. The results are expressed as micrograms per cubic metre (ug m^{-3}) of air sampled. The sampler is operated continuously for a 24 hour period every third day resulting in nine to ten samples per month. In addition to total loading, the filter can also be analyzed for the presence of several elements by atomic absorption.

In 1975, the filters from the high volume air sampler located in Wawa were analyzed for total particulate loading and also for the following elements; arsenic, iron, lead and zinc. The available data are shown in Table 15 of the appendix.

A total of thirty-one high volume samples were collected over the period from June 26 to October 15. The data indicate that the Ontario Ministry of the Environment criterion for a 24 hour period (120 ug m^{-3}) for total suspended particulates was exceeded on eight occasions during that period of time as shown in the Table below.

Sampling Period	No. of Samples	Maximum 24 Hr. Value (ug m^{-3})	No. of Times Above 24 Hr. Criterion
June	2	262	1
July	8	395	3
August	11	180	4
September	6	104	Nil
October	4	98	Nil
June 26-Oct.15	31	395	8

The criterion was exceeded once in June, three times in July, and four times in August. The maximum 24 hour reading was 395 ug m^{-3}.

The average monthly loadings were computed and plotted as shown in Figure 6. The numbers in parentheses represent the number of samples for which the average was taken. From the plot it is observed that the average loadings were elevated especially during June, July and August. For the thirty-one samples collected the geometric mean is 85 ug m^{-3}, which is well above the annual criterion of 60 ug m^{-3}. The excessive loadings encountered during the summer

months however, are the result of dust blowing from a nearby parking lot and are not related to the sinter plant operation.

The levels of As, Pb and Zn in the suspended particulates were generally quite low as indicated in the Table below.

Element	Maximum 24 Hour Value (ug m^{-3})	O.M.E. 24 Hour Criterion (ug m^{-3})	Number of Times Above Criterion
As	0.210	25	Nil
Fe	17.26	No Criterion	
Pb	0.74	5	Nil
Zn	0.25	No Criterion	

From the results of the high volume air sampling in Wawa for 1975 it can be concluded that most of the suspended particulates consisted of dust originating from a parking lot adjacent to the sampling site. As mentioned earlier a second high volume sampler will be installed on Hillcrest Avenue in Wawa in March of this year. At this location, thelevels of suspended particulates will hopefully be more representative of the particulate emissions from the Algoma Ore Division Sinter Plant.

VI RESULTS OF SNOW SAMPLING PROGRAM:

At each sample site five circular cores (8 cm in diameter and 18 cm in length) of snow were collected and allowed to melt at room temperature overnight. The five samples were then combined to form a composite sample for each site. The volume of the sample was then measured and a pH measurement taken. The composite sample from each site was then divided into two equal parts and one part was acidified with concentrated nitric acid to prevent the metallic elements from plating out on the sides of the plastic bottles. The acidified portion of the sample was analyzed for iron, arsenic, sodium and zinc and the non-acidified sample for sulphate and chloride.

Results:

Table 16 contains the results of the chemical analysis of the Wawa snow samples. The locations of the sample sites in relation to the Algoma Ore Division sinter plant are listed on page 51. The number beside each location corresponds to the number at each site marked on the map in Figure 8.

The control location for vegetation and soil sampling in previous

years has been the Obatanga Provincial Park, 56 km northwest of Wawa. It appears that the snow sample collected, at this site was in a locally contaminated area. Therefore control values have been calculated by averaging the levels of the various elements at the three locations furthest to the northeast of the sinter plant. These are the sites marked '9', '10' and '11' on page 30.

The zinc concentrations in all samples were below the detectable level of 0.03 ppm and consequently no zinc results are included in this report.

The calculated control pH was 4.30. The pH of the samples ranged from 4.20 to 6.01. The pH at the 4 locations closest to the sinter plant (numbers 12, 13, 14 and 17 on page 30) are slightly higher than the other samples.

Both the sodium and chloride levels were elevated at a number of sites. These sites were adjacent to roadways and the elevated levels were probably caused by the presence of salt which is applied as a de-icer to road surfaces.

The sulphate concentration in the snow sample from the site 1.6 km south of the sinter plant was 16.0 ppm, while the level in the control was 1.0 ppm. Sulphate concentrations in samples from the other 3 sites (numbers 12, 13 and 14) close to the sinter plant were also elevated.

The only elevated calcium concentration, 12.0 ppm, was in the sample from the location 1.6 km southwest of the sinter plant. The control calcium concentration was 1.0 ppm.

The arsenic concentration in 6 of the 18 samples was below the detectable level of 5 parts per billion. Concentrations of arsenic in the samples collected in the Town of Wawa ranged from 17 to 32 parts per billion. The highest arsenic level, 230 parts per billion was in the sample collected 1.6 km southwest of the sinter plant.

In general the iron concentrations were highest at the locations closest to the sinter plant and decreased with increased distance from the source. The highest iron concentration, 88 ppm was found in the sample collected 1.6 km south of the sinter plant. The iron concentration in the control was 0.13 ppm.

In Figure 9 the iron concentrations for the complete sample are plotted against distance from the source. In Figure 10 the iron concentrations in the samples from northeast of the source only are plotted against distance from the source. The correlation coefficient for Figure 10 is -.875 and for Figure 9 it is -.919 There is a better correlation between concentration and distance in the samples to the northeast than in the total sample. There was a low correlation coefficient between distance and concentration for the other elements.

Conclusions:

Elevated levels of a number of elements, particularly sulphur,

iron and arsenic, were found in fresh snow samples collected in the vicinity of the AOD sinter plant in January, 1975. Since the concentrations of these elements were higher at sites closest to the sinter plant and decreased with increased distance from the plant it can be assumed the elevated levels were caused by the sinter plant emissions. It is recommended that the snow sampling program be continued in 1976 with certain modifications, ie: sample during January and February and increase the number of sample sites in the Town of Wawa and discontinue sampling at certain locations to the northeast of Wawa.

VII SUMMARY AND CONCLUSIONS:

Emissions of the Algoma Ore Division sinter plant were monitored by the Ontario Ministry of the Environment during 1975. Two continuous SO_2 monitors, one high volume sampler and a network of 10 sulphation candles made up the monitoring system. Concentrations of SO_2, sufficient to produce acute injury on vegetation were recorded several times during the growing season and the incidence and extent of the injury were mapped during monthly surveillance trips.

Samples of vegetation and soil were collected for chemical analysis during July and August.

During 1976, the Ministry will expand, and in some cases modify its air quality assessment studies in the Wawa area. Data obtained during 1976 and subsequent years will be useful in assessing the effectiveness of the abatement program currently in effect at the sinter plant and in determining the effect of the emissions on the local environment.

VIII ACKNOWLEDGEMENTS:

The author wishes to express his thanks to: Mr. W. J. Gibson, Manager, Technical Support Section and Dr. D. Balsillie, Chief, Air Quality Assessment for supervision, advice and support; Dr. S. N. Linzon, and staff of the Phytotoxicology Section, Air Resources Branch for technical advice and handling of the vegetation and soil samples; Mr. A. C. Rayner and the staff of the Air Quality Laboratory for chemical analysis of the vegatation and soil samples (Mr. R. Wills), and for analysis of the high volume filters and lead peroxide candles (Mr. M. Metzger and Dr. B. Foster); Mr. K. Waldie and his staff for maintenance of the air quality monitoring equipment; Mr. R. Potvin and Mr. N. Jain for compiling the air quality data; Mr. P. J. Temple and Mr. A. W. Hill for their assistance in the plant population study program; the staff of the Ministry of Natural Resources for arranging air transportation in the Wawa area; Mr. D. Stewart of the Algoma Steel Corporation for supplying production data; Mr. W. D. McIlveen for assistance with the field work and laboratory analysis of pathology samples and Mrs. J. Hatton and Mrs. D. Labre for secretarial assistance. As a result of the co-ordinated effort of all these people, the presentation of this report was made possible.

APPENDIX

Plot Locations and Site Descriptions

Plot #1 Location:

On the Magpie River approximately 1.6 km southwest of the Algoma Ore Division sinter plant. This plot was established in May of 1975.

Site Description:

This plot is located on a well drained site. The area is covered with a semi-mature stand of white birch, trembling aspen, jack pine and spruce. The ground cover vegetation is made up of a large number of grasses and herbacious plants.

Plot #2 Location:

Lucy Pit, Algoma Ore Division approximately 10 km northeast of Wawa in the "Total Kill" section of the fume damage area.

Site Description:

A well drained area with shallow soil profile and many rock outcrops. The area is sprarsely covered with a stand of small white birch, trembling aspen and Manitoba maple. The ground cover vegetation is composed of a variety of plant species.

Plot #3 Location:

Parks Lake, 16 km northeast of Wawa in the "Total Kill" section of the fume damage area.

Site Description:

An open well drained site with a shallow soil profile with several rock outcrops. The area is sprarsely covered with a stand of small white birch, Manitoba maple and alder. The ground cover vegetation is made up mainly of grasses and blueberry plants.

Plot #4 Location:

Finger Lake, 19 km northeast of Wawa in the "Total Kill" section of the fume damage area.

Site Description:

An open well drained site. The soil profile is shallow and rock outcrops are common. The area is sparsely covered with a stand of small white birch and Manitoba maple.

Plot #5 Location:

Perry Lake, 26 km northeast of Wawa in the "Heavy Kill" section of the fume damage area.

Site Description:

A poorly drained site with organic soil. Beaver have removed all the mature aspen trees leaving a sparse stand of alder and white birch.

Plot #6 Location:

Garbe Lake, 30 km northeast of Wawa in the "Heavy Kill" section of the fume damage area.

Site Description:

A well drained site, with a shallow soil profile. The area is covered with a semi-mature stand of white birch and spruce.

Plot #7 Location:

Goudreau, approximately 35 km northeast of Wawa in "Light Damage" section of the Fume Damage Area.

Site Description:

A well drained site with a southern exposure. The soil profile is shallow and rock outcrops are common. The area is moderately covered with a young stand of white birch and trembling aspen.

Plot #8 Location:

Troupe Lake, 40 km northeast of Wawa in the "Light Damage" section of the Fume Damage Area. This plot was established in June of 1974 replacing a plot on the island on Herman Lake. Expansion of a tourist operation on the island interfered with the plot and making it necessary to find a new location.

Site Description:

A well drained rocky site with a shallow soil profile. The area is forested with a semi-mature stand of trembling aspen, white birch and spruce.

Plot #9 Location:

A control location approximately 45 km northeast of Wawa. This plot was established along the Dubreuil Road in June of 1974 and replaces the former control plot at Crouche Lake. Road construction and wind damage made it necessary to relocate this plot.

Site Description:

A well drained sandy soil. The area is covered with a stand of small white birch, trembling aspen and spruce. The undercover consists of alder and a wide range of grasses, sedges, blueberry and other plant species.

Plot #10 Location:

A control location in the Obatanga Provincial Park, approximately

56 km northwest of Wawa.

Site Description:

A poorly drained location, covered with a mature stand of white birch, trembling aspen, spruce and balsam fir.

** Personnel from the Ministry of Natural Resources at Wawa have mapped the Wawa Fume Damage Area by air for the past several years and the terms "Total Kill", "Heavy Damage" and "Light Kill" are the terms used by them to describe the three injury zones.

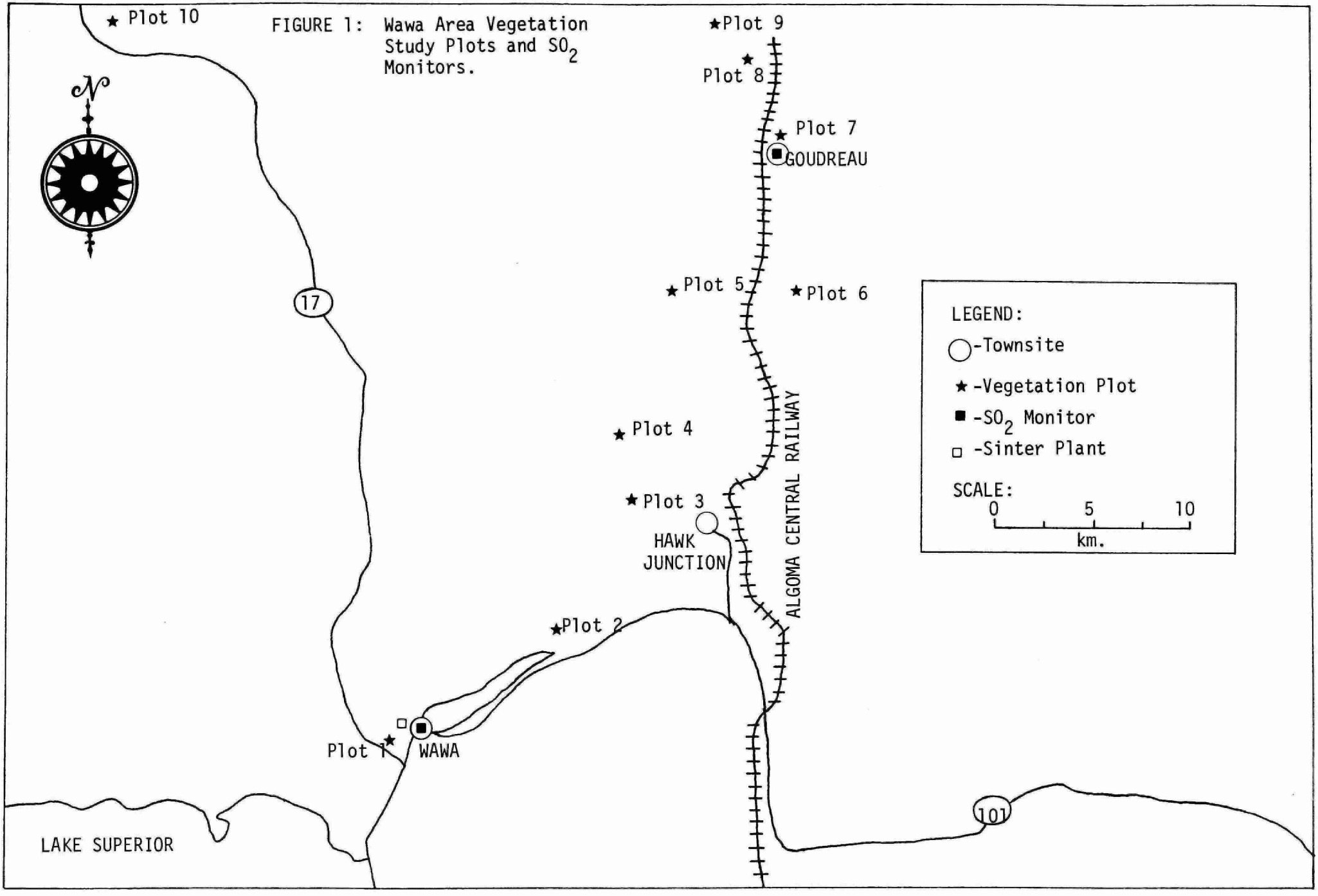


FIGURE 1: Wawa Area Vegetation Study Plots and SO_2 Monitors.

FIGURE 2:
MONTHLY PRODUCTION AND EMISSIONS AT
ALGOMA ORE DIVISION SINTER PLANT, WAWA
MAY - SEPTEMBER, 1975

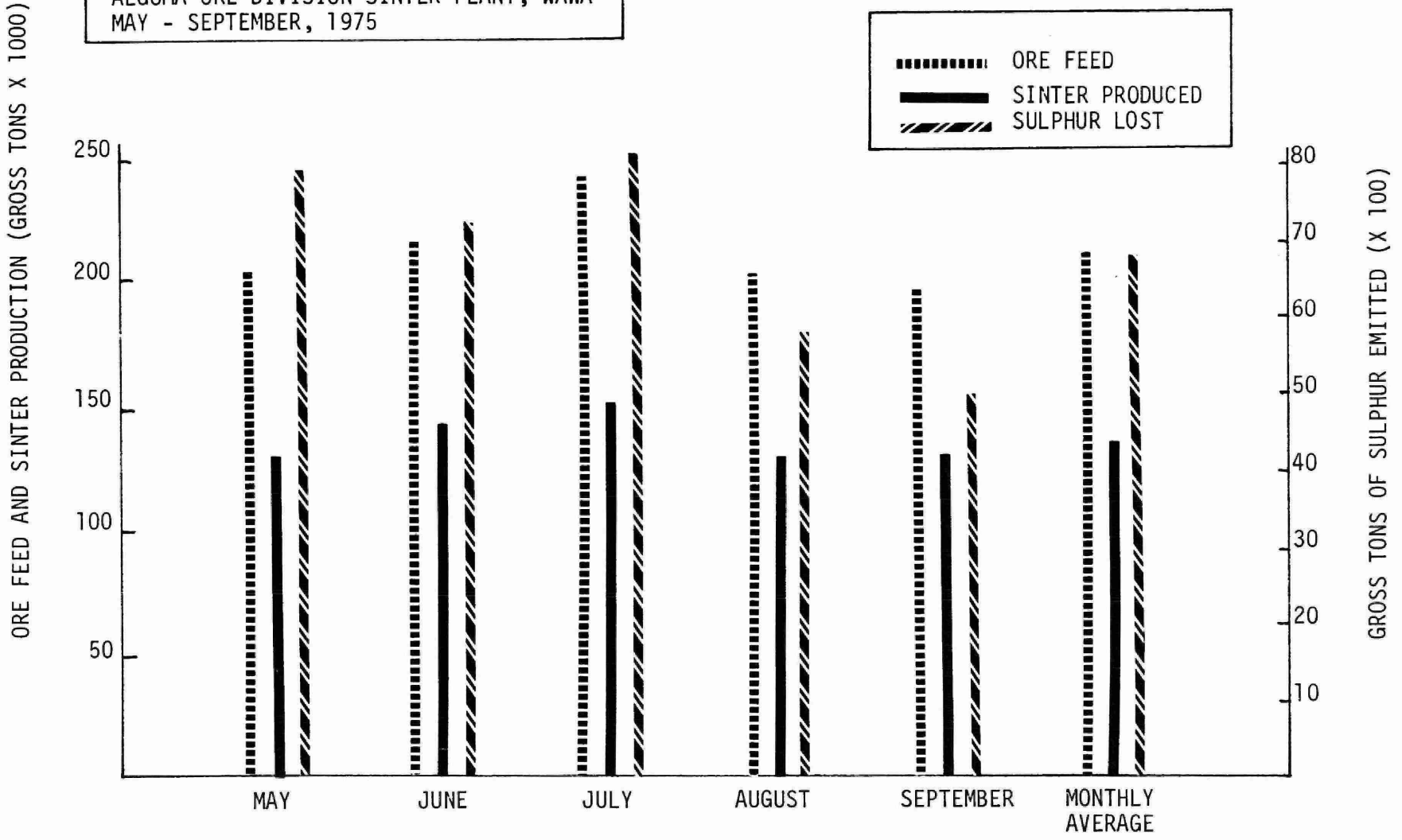


FIGURE 3:

RELATIONSHIP BETWEEN SULPHATION RATES AND TOTAL SULPHUR IN VEGETATION SAMPLES COLLECTED IN THE WAWA AREA 1974

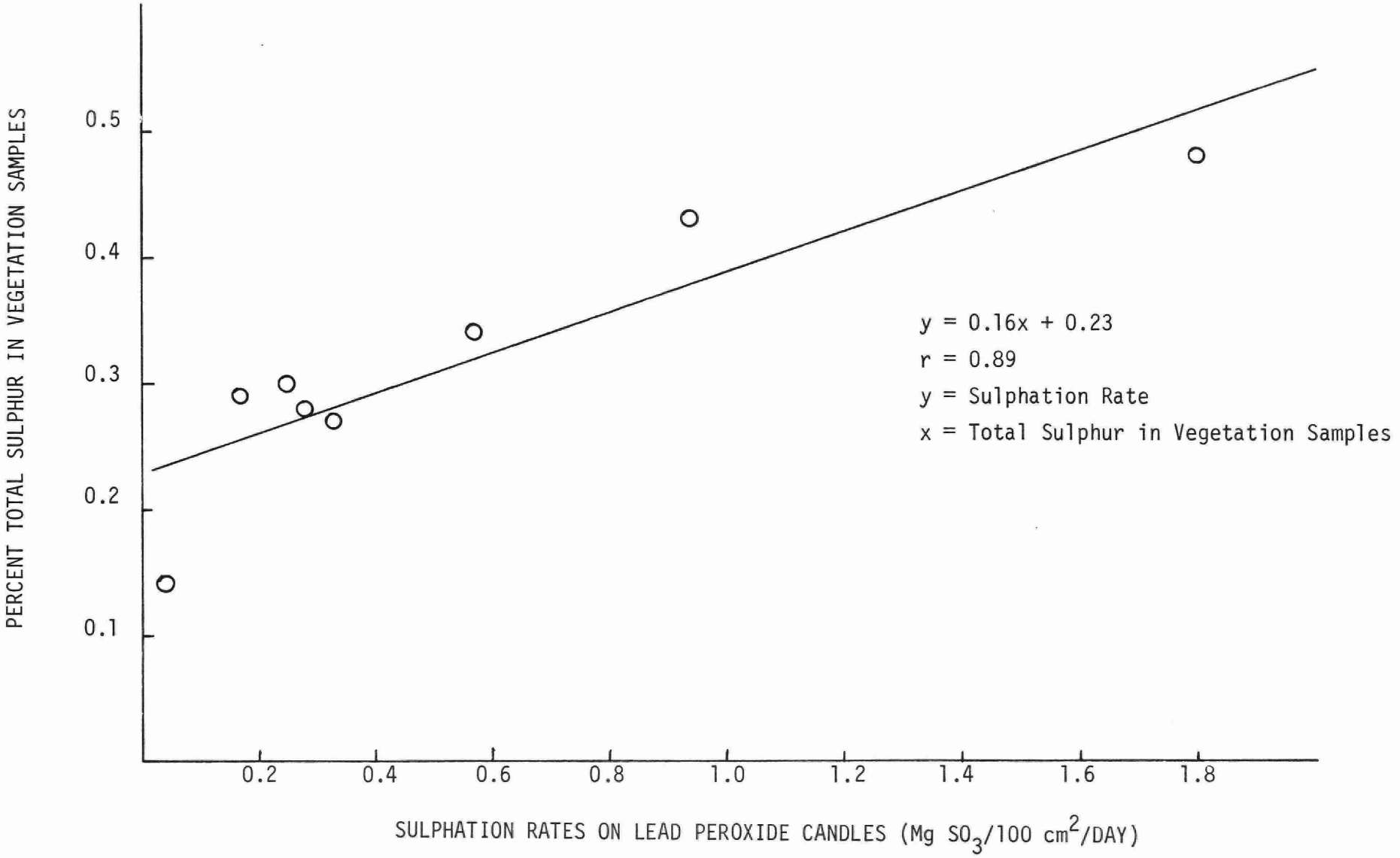
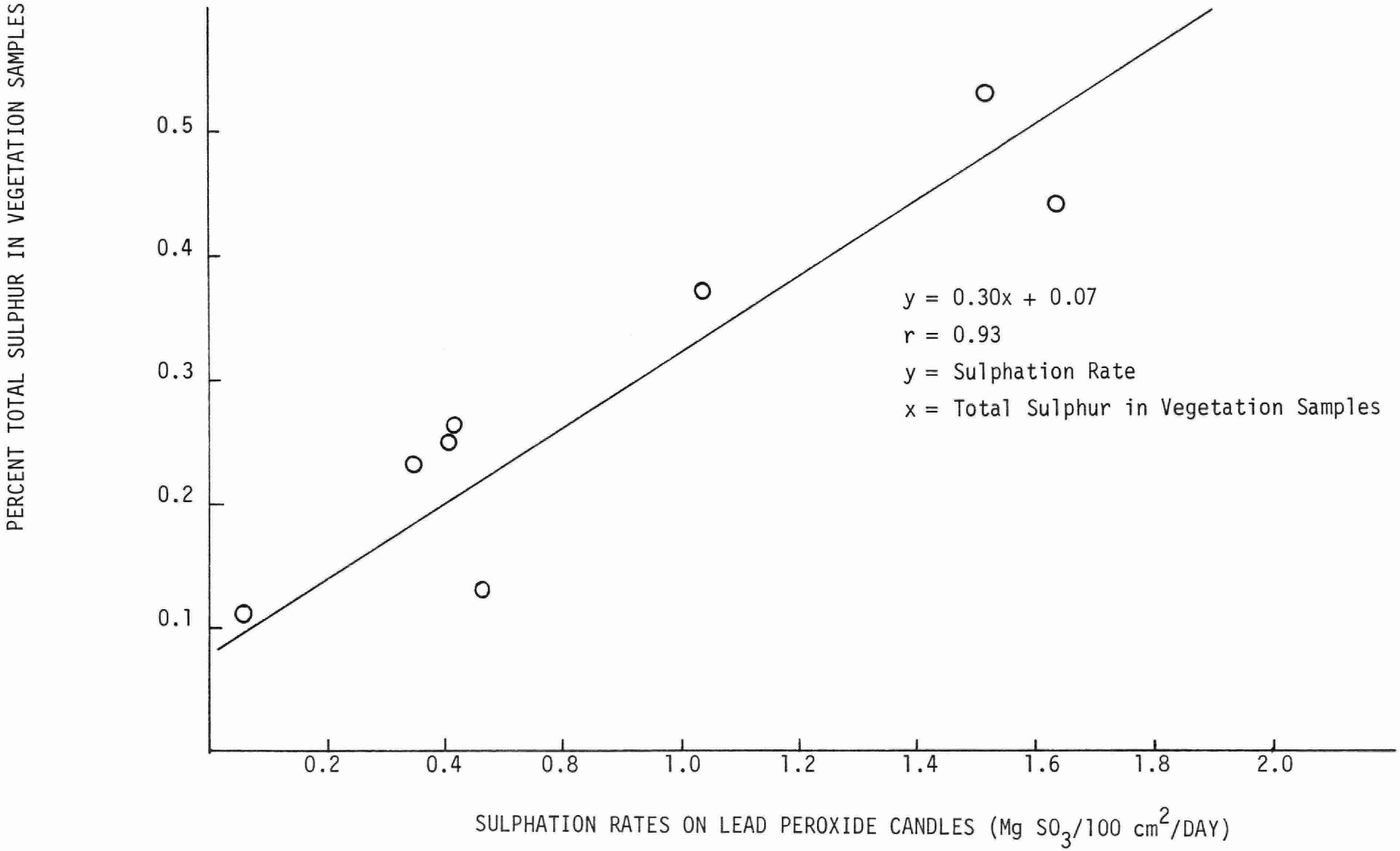


FIGURE 4:

RELATIONSHIP BETWEEN SULPHATION RATES AND TOTAL SULPHUR IN VEGETATION SAMPLES COLLECTED IN THE WAWA AREA- 1975



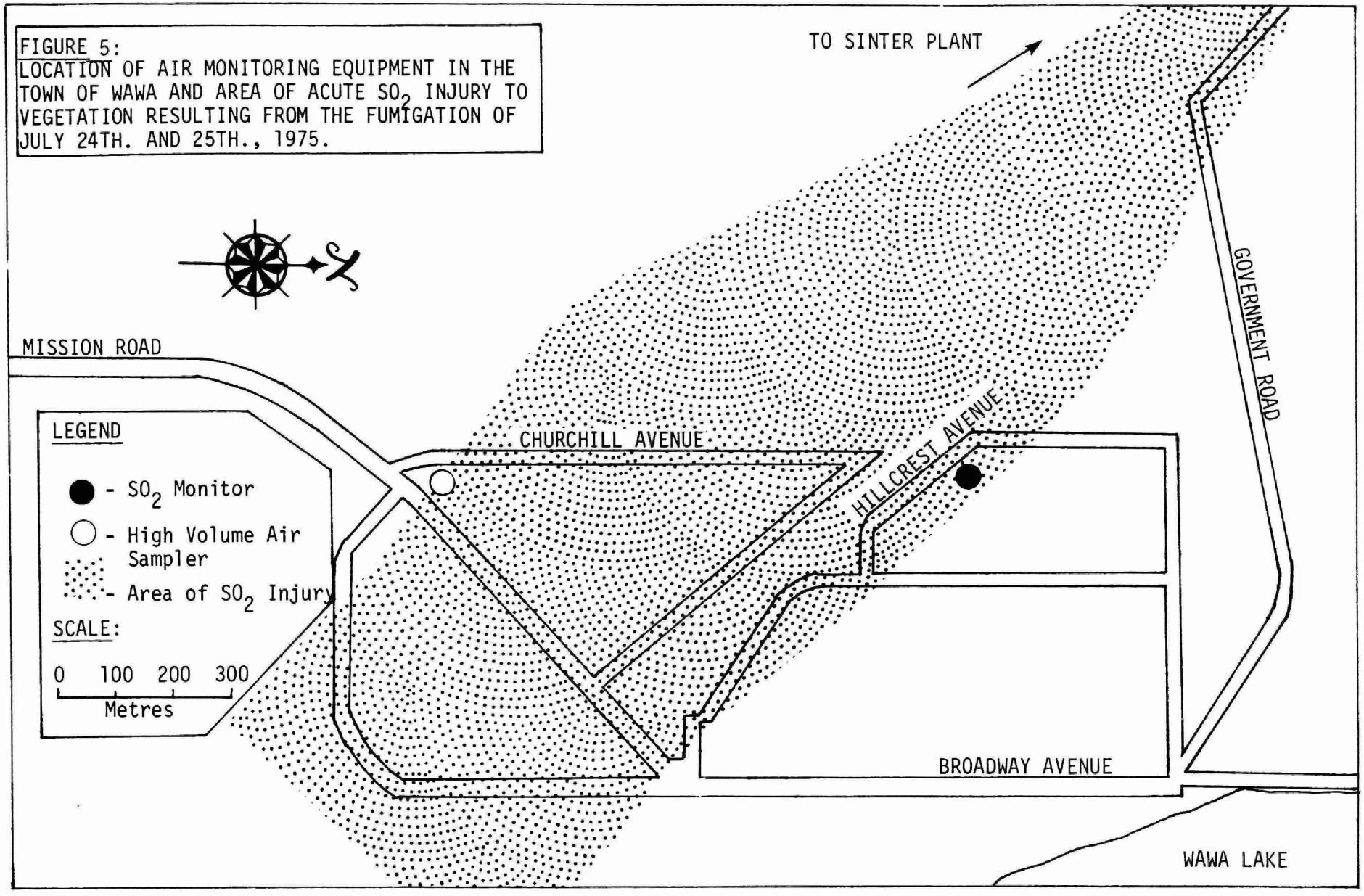
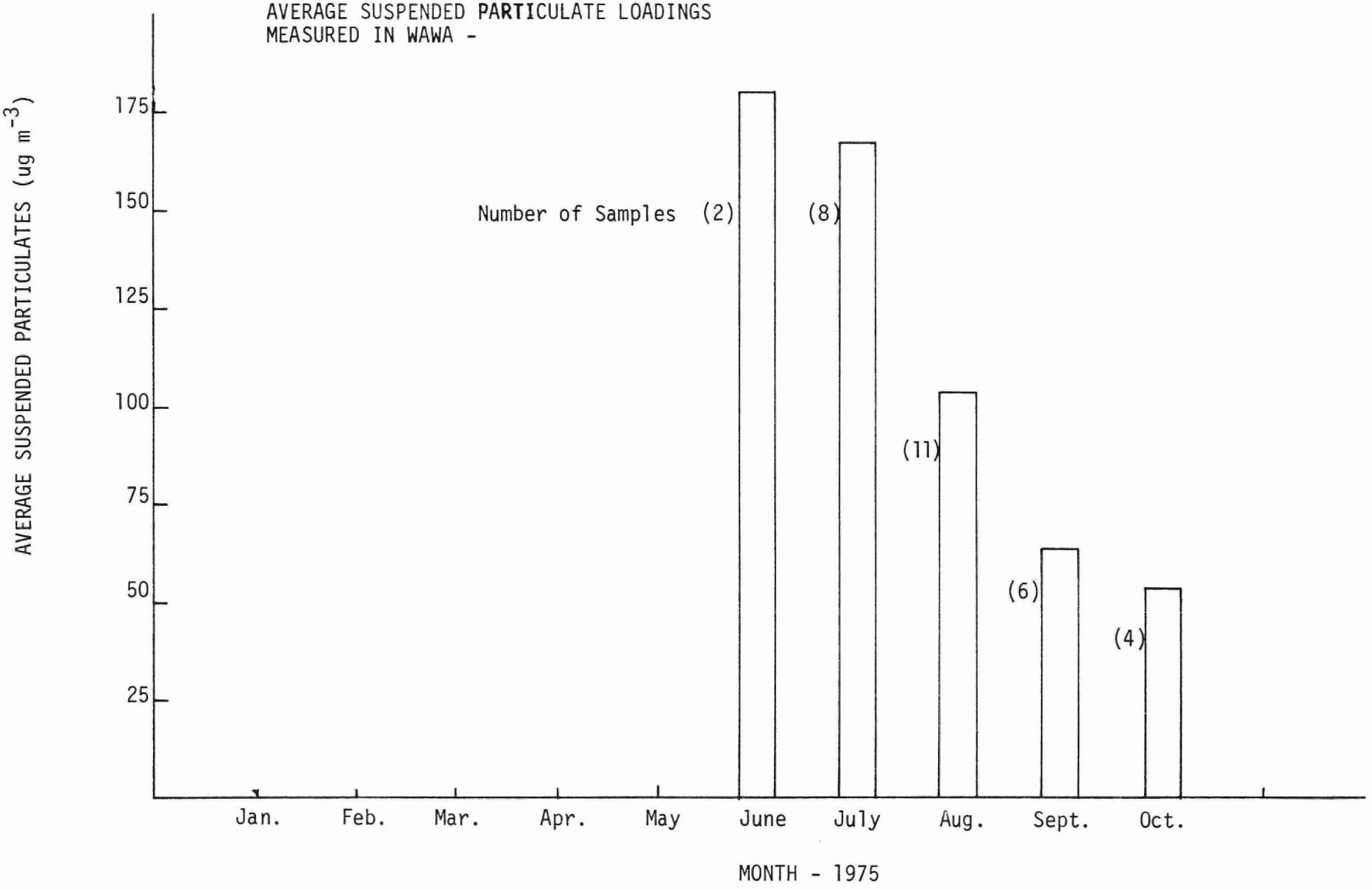


FIGURE 5:
LOCATION OF AIR MONITORING EQUIPMENT IN THE TOWN OF WAWA AND AREA OF ACUTE SO_2 INJURY TO VEGETATION RESULTING FROM THE FUMIGATION OF JULY 24TH. AND 25TH., 1975.

FIGURE 6:

AVERAGE SUSPENDED PARTICULATE LOADINGS
MEASURED IN WAWA -



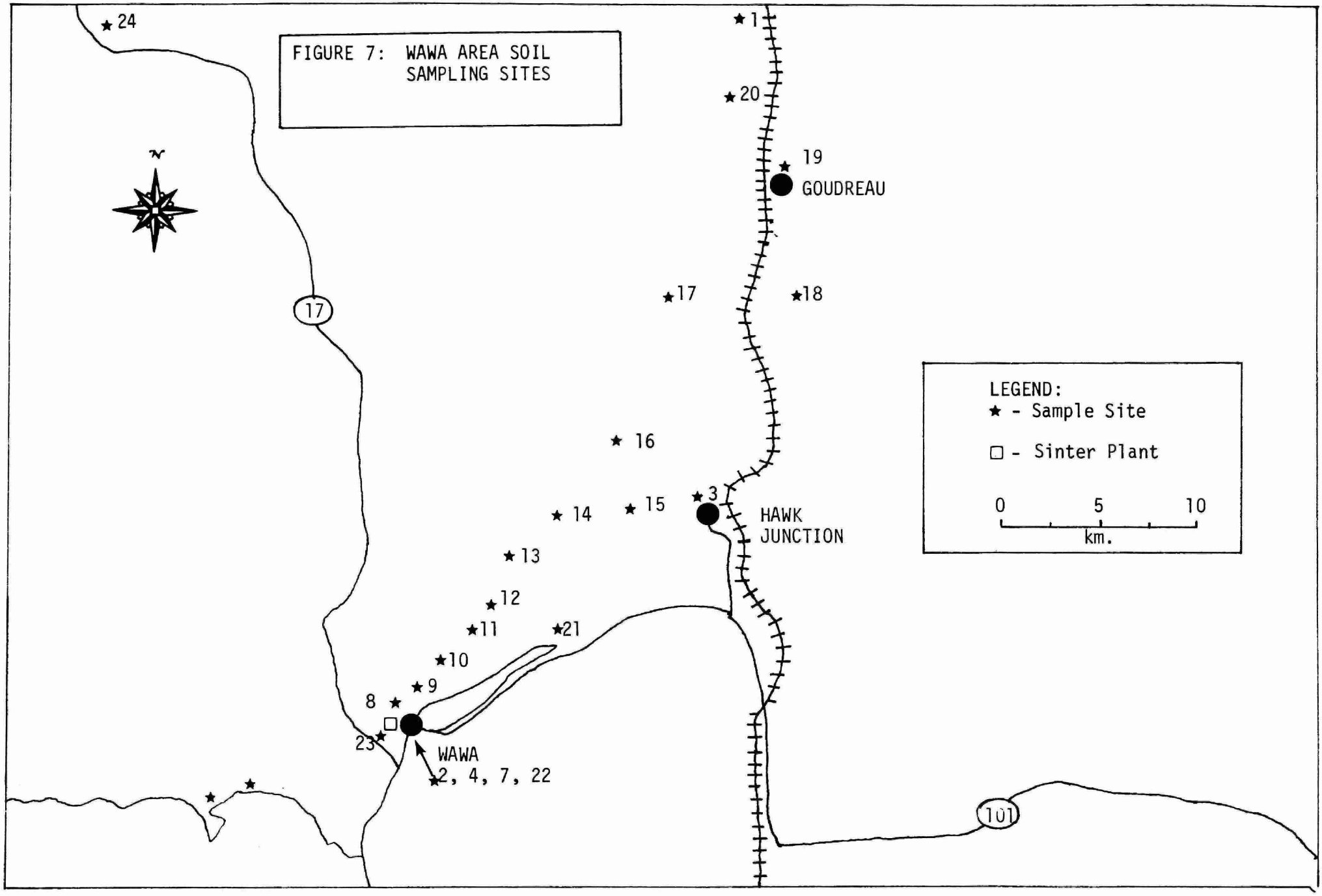


FIGURE 7: WAWA AREA SOIL SAMPLING SITES
N
24
1
20
19
GOUDREAU
17
18
17
16
3
15
14
HAWK JUNCTION
13
12
11
21
10
9
8
23
WAWA
2, 4, 7, 22
101
LEGEND:
★ - Sample Site
□ - Sinter Plant
0 5 10
km.

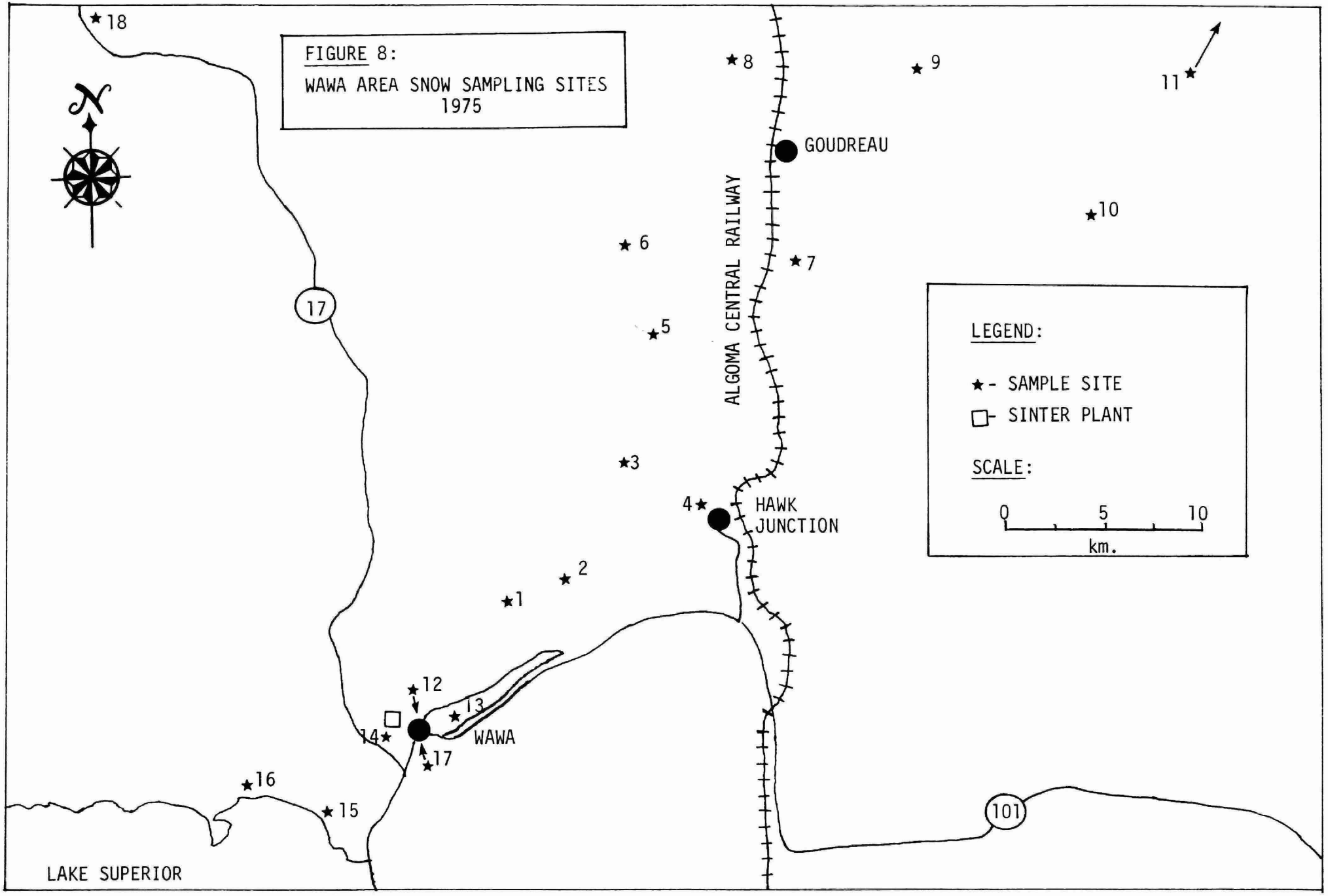
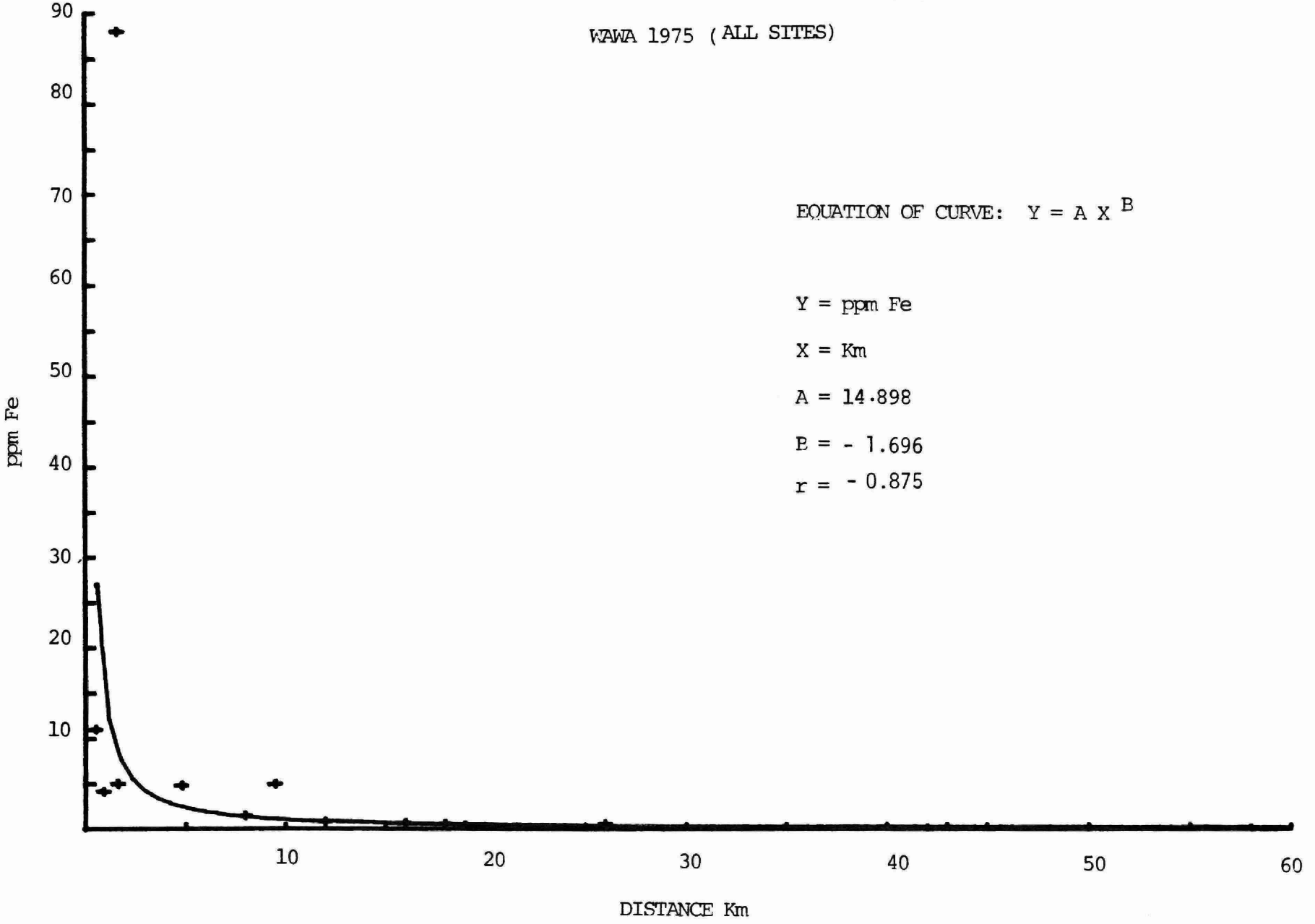


FIGURE 8:
WAWA AREA SNOW SAMPLING SITES
1975
N
18
8
9
11
GOUDREAU
ALGOMA CENTRAL RAILWAY
10
6
7
17
5
LEGEND:
★- SAMPLE SITE
□- SINTER PLANT
SCALE:
0 5 10
km.
3
4
HAWK
JUNCTION
2
1
12
13
14
WAWA
17
16
15
101
LAKE SUPERIOR

FIGURE- 9: CONCENTRATION OF IRON IN SNOW MELT WATER

WAWA 1975 (ALL SITES)



EQUATION OF CURVE: $Y = A X^{B}$

Y = ppm Fe

X = Km

A = 14.898

B = - 1.696

r = - 0.875

FIGURE- 10: CONCENTRATION OF IRON IN SNOW MELT WATER SAMPLES

WAWA 1975 (NORTHEAST SITES ONLY)

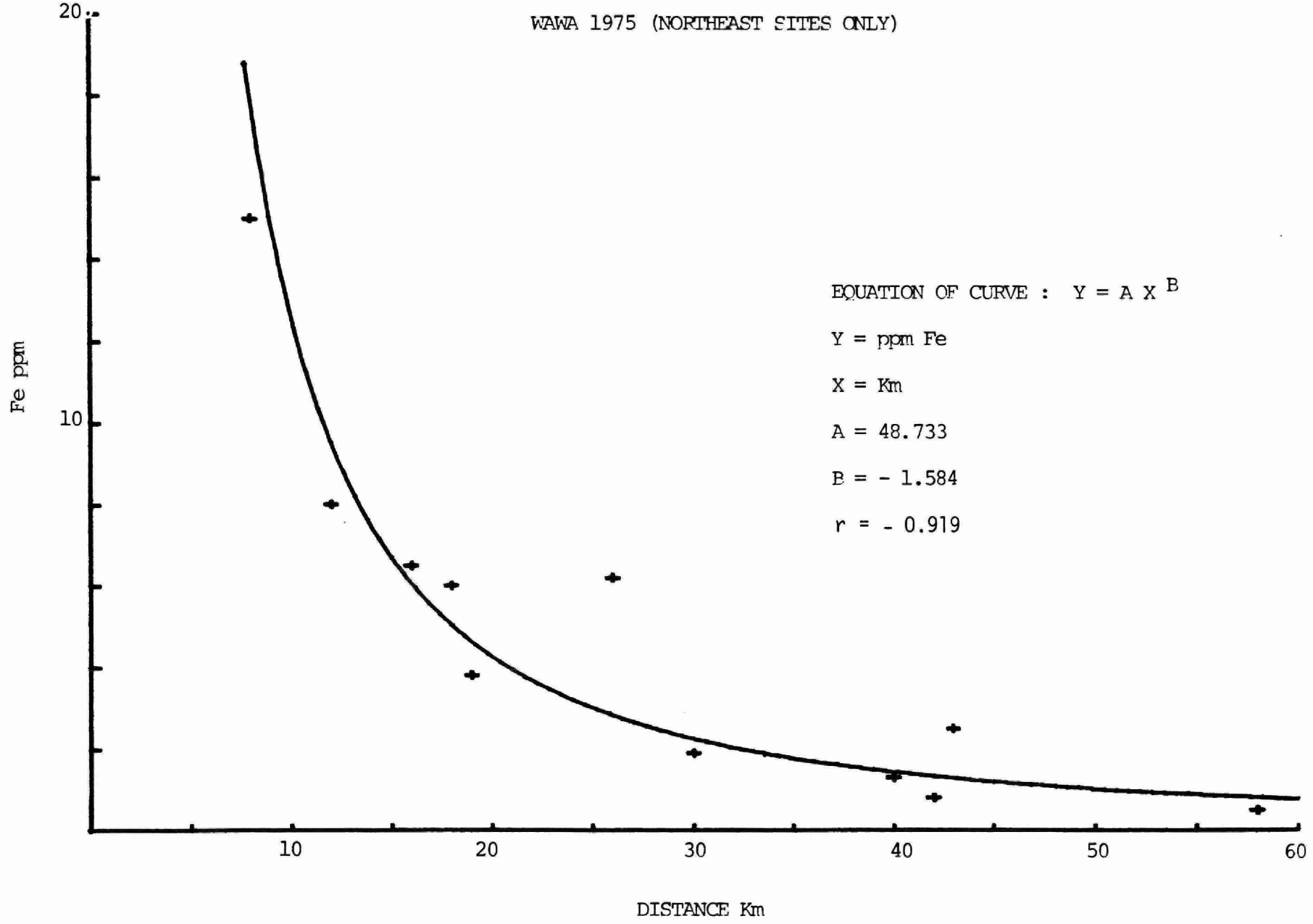


Table 1

*MONTHLY (MAY - OCTOBER, 1975) PRODUCTION AND EMISSIONS DATA FROM THE ALGOMA ORE DIVISION SINTER PLANT AT WAWA (DRIED WEIGHTS AND ASSAYS)

Month	Ore Feed Gross Tons	Sulphur in Feed %	Sulphur in Feed G.T.	Sinter Produced G.T.	Sulphur in Sinter %	Sulphur in Sinter G.T.	G.T. Of Sulphur Lost as SO_2
May	205,317	3.88	7,966	130,771	.072	94	7,872
June	218,682	3.37	7,370	144,087	.091	131	7,239
July	242,954	3.43	8,333	152,615	.104	159	8,174
August	206,429	2.87	5,925	131,056	.090	118	5,807
September	199,750	2.55	5,094	133,856	.077	103	4,991
TOTAL	1,073,132	16.10	34,688	692,385	.434	605	34,083
5 Month Average	214,626	3.22	6,938	138,477	.087	121	6,817

* Data Supplied by Algoma Ore Division, The Algoma Steel Corporation, Ltd.

Table 2

SUMMARY OF SULPHUR DIOXIDE DATA RECORDED
AT 29 HILLCREST AVENUE, WAWA, DURING 1975

Month	Total Sampling Time (Hrs.)	Total Hours of SO_2	%	Hours Above 0.25 ppm	%	0.50 ppm	%	1.00 ppm	%	Maximum 1-Hr. Concentration-ppm	Date
May	256	141	55	0	0.0	0	0.0	0	0.0	0.25	May 26th.
June	720	188	26	0	0.0	0	0.0	0	0.0	0.22	June 29th.
July	723	38	5	17	45	13	34	10	26	2.13	July 25th.
August	226	7	3	0	0.0	0	0.0	0	0.0	0.03	Aug.21st.
September	718	40	6	12	30	3	8	1	3	1.18	Sept.26th.
October	717	32	4	10	24	5	16	2	6	1.35	Oct. 3rd.
SEASON	3360	446	13	39	9	21	5	13	3	2.13	July 25th.

Table 3

SUMMARY OF SULPHUR DIOXIDE DATA
RECORDED AT WAWA DURING THE GROWING SEASONS
1972 - 1975

Year	Total Sampling Time (Hours)	Hours of SO_2	%	* Maximum Concentration ppm	# of Potentially Injurious Fumigations	Average ppm for SO_2 Periods	Total Periods
				-------June-------			
1975	720	188	26	0.22	0	0.02	0.01
1974	694	143	21	0.56	0	0.02	0.01
1973	704	424	60	0.17	0	0.01	0.01
1972	536	9	2	0.40	0	0.05	0.01
				-------July-------			
1975	723	38	5	2.13	1	0.52	0.03
1974	713	143	20	1.31	1	0.07	0.02
1973	744	173	23	0.65	0	0.02	0.01
1972	738	14	2	0.26	0	0.05	0.01

* Concentrations for 1972 and 1973 are for ½ hour periods while concentrations for 1974 and 1975 are for one hour periods.

Table 3 (Con't)

SUMMARY OF SULPHUR DIOXIDE DATA
RECORDED AT WAWA DURING THE GROWING SEASONS
1972 - 1975

Year	Total Sampling Time (Hours)	Hours of SO_2	%	Maximum Concentration ppm	# of Potentially Injurious Fumigations	Average ppm for SO_2 Periods	Total Periods
				-------August-------			
1975	226	7	3	0.03	0	0.02	0.01
1974	743	102	14	0.42	0	0.02	0.01
1973	731	55	8	0.63	0	0.03	0.01
1972	739	32	4	1.22	0	0.09	0.01
				-------September-------			
1975	718	40	6	1.18	2	0.21	0.01
1974	719	73	10	0.98	2	0.18	0.02
1973	717	134	19	1.79	3	0.13	0.02
1972	418	16	4	0.39	0	0.11	0.01
				-------SEASON-------			
1975	2387	273	11	2.13	3	0.12	0.01
1974	2869	461	16	1.31	3	0.06	0.01
1973	2896	786	27	1.79	3	0.04	0.01
1972	2431	71	3	1.22	0	0.08	0.02

Table 4

SUMMARY OF SULPHUR DIOXIDE DATA RECORDED AT GOUDREAU DURING 1975

Month	Total Sampling Time (Hrs.)	Total Hours of SO_2	%	Hours Above 0.25 ppm	%	0.50 ppm	%	1.00 ppm	%	Maximum 1-Hr. Concentration-ppm	Date
May	245	67	27	0	0.0	0	0.0	0	0.0	0.25	May 30th.
June	718	238	33	1	0.4	0	0.0	0	0.0	0.35	June 2nd.
July	738	466	63	1	0.2	0	0.0	0	0.0	0.32	July 31st.
August	742	118	16	9	7.6	0	0.0	0	0.0	0.40	Aug. 16th
September	253	151	60	0	0.0	0	0.0	0	0.0	0.25	Sept. 27th.
SEASON	2696	1040	39	11	1.1	0	0.0	0	0.0	0.40	Aug. 16th.

Table 5

SUMMARY OF SULPHUR DIOXIDE DATA
RECORDED AT GOUDREAU DURING THE GROWING SEASONS 1972 - 1975

Year	Total Sampling Time (Hours)	Hours of SO_2	%	Maximum Concentration ppm	# of Potentially Injurious Fumigations	Average ppm for SO_2 Periods	Total Periods
				-------June-------			
1975	718	238	33	0.35	0	0.03	0.01
1974	462	151	33	0.46	0	0.08	0.03
1973	678	185	27	0.46	0	0.06	0.02
1972	446	82	33	0.08	0	0.03	0.01
				-------July-------			
1975	738	466	63	0.32	0	0.03	0.02
1974	413	166	34	0.87	1	0.06	0.02
1973	592	98	17	0.97	1	0.08	0.01
1972	538	160	30	0.21	0	0.06	0.02

Table 5 (Con't)

SUMMARY OF SULPHUR DIOXIDE DATA
RECORDED AT GOUDREAU DURING THE GROWING SEASONS 1972 - 1975

Year	Total Sampling Time (Hours)	Hours of SO_2	%	Maximum Concentration ppm	# of Potentially Injurious Fumigations	Average ppm for SO_2 Periods	Total Periods
				-------August-------			
1975	742	118	16	0.40	0	0.07	0.01
1974	243	132	42	0.23	0	0.03	0.01
1973	702	135	19	0.53	0	0.07	0.01
1972	626	242	39	0.32	0	0.02	0.01
				-------September-------			
1975	253	151	60	0.25	0	0.04	0.02
1974	656	270	41	0.23	0	0.02	0.01
1973	714	76	11	0.97	0	0.09	0.01
1972	672	126	19	0.10	0	0.01	0.01
				-------SEASON-------			
1975	2451	973	40	0.40	0	0.04	0.01
1974	1774	719	40	0.87	1	0.04	0.02
1973	2686	494	18	0.97	1	0.07	0.01
1972	2282	610	27	0.32	0	0.5	0.01

Table 6:

SULPHATION RATES IN MGM SO_3/100 cm^2/DAY ON LEAD PEROXIDE CANDLES DURING JUNE, JULY, AUGUST AND SEPTEMBER OF 1975 AT THE VEGETATION STUDY PLOTS COMPARED TO THE 1970-74 MEAN FOR EACH LOCATION

Plot No.	Location in Relation to the Sinter Plant	Mid May-Mid June		Mid June-Mid July		Mid July-Mid Aug.		Mid Aug.-Mid Sept.		Season	
		1970-74 (Mean)	1975	1970-74 (Mean)	1975	1970-74 (Mean)	1975	1970-74 (Mean)	1975	1970-74 (Mean)	1975
1	1.6 km SW	--	0.20	--	0.12	--	0.17	--	0.15	--	0.16
2	10 km NE	--	1.33	--	2.15	--	1.23	--	0.56	--	1.32
3	16 km NE	1.47	0.97	*2.00	2.57	0.88	1.83	**0.69	0.39	1.31	1.44
4	19 km NE	0.93	0.56	1.05	1.66	1.00	0.92	0.43	0.21	0.85	0.84
5	26 km NE	0.44	0.32	0.44	1.79	0.19	0.52	0.18	0.11	0.31	0.42
6	30 km NE	0.38	0.17	0.58	0.58	0.56	0.47	0.26	--	0.44	0.41
7	35 km NE	0.37	0.15	0.36	0.45	0.19	0.48	0.18	--	0.28	0.35
8	38 km NE	0.27	0.34	0.27	0.63	0.11	0.46	0.17	--	0.20	0.47
9	61 km NE	0.11	0.04	0.15	0.09	0.6	0.08	0.07	0.04	0.10	0.06
10	56 km NW	0.05	0.03	0.05	0.05	0.03	0.03	0.04	0.03	0.04	0.04

* Mean 1971-1974

** Mean 1972-1974

O.M.E. Criterion for Sulphation Rate:
- 0.70 mgm SO_3/100 cm^2/day for a 30 day period.

Table 7:

CROWN CONDITION OF TREES AND SHRUBS IN WAWA VEGETATION STUDY PLOTS, AUGUST 1975 COMPARED TO AUGUST/74*

Plot No.	Year Established	Location and Direction From Sinter Plant	1A Healthy	1B, 2A,2B Some Decline	3A, 3B, 4A, 4B Moderate Decline	6A, 6B Dead
1	1975	1.6 km SW	11 --	9 --	----	0 (0)
2	1974	10 km NE	19 (20)	----	1 (0)	0 (0)
3	1969	16 km NE	10 (5)	----	7 (12)	3 (3)
4	1969	19 km NE	8 (12)	4 (0)	5 (5)	3 (3)
5	1969	26 km NE	7 (7)	----	7 (8)	6 (5)
6	1969	30 km NE	6 (16)	13 (0)	0 (3)	1 (1)
7	1969	35 km NE	10 (10)	5 (0)	0 (5)	5 (5)
8	1974	40 km NE	13 (20)	6 (0)	1 (0)	----
9	1974	45 km NE	18 (20)	1 (0)	1 (0)	----
10	1969	56 km NW	17 (12)	2 (0)	-- (7)	1 (1)
Total			119 (122)	40 (0)	22 (40)	19 (18)

* 1974 Figures in Brackets

Table 8:

CHANGES IN CROWN CONDITIONS OF TREES AND SHRUBS IN THE WAWA AREA VEGETATION STUDY PLOTS BETWEEN YEAR OF ESTABLISHMENT AND AUGUST/75

Plot No.	Year Established	Location In Relation to Sinter Plant	Number of Trees and Shrubs Whose Condition Has:			
			Remained Constant	Improved	Declined	Dead Individuals as of August, 1975
1	1975	1.6 km SW	--	--	--	0
2	1974	10 km NE	20	0	--	0
3	1969	16 km NE	5	7	8	3
4	1969	19 km NE	4	7	9	3
5	1969	26 km NE	5	5	10	6
6	1969	30 km NE	6	5	9	1
7	1969	35 km NE	5	5	10	5
8	1974	40 km NE	13	-	7	0
9	1974	45 km NE	18	0	2	0
10	1969	56 km NW	9	8	3	1
Totals:			85	37	58	19

Table 9: SUMMARY OF DATA FROM WAWA AREA MICROPLOT STUDIES

Plot #	Location in Relation to Sinter Plant	Trees		Shrubs		Herbacious Plants		TOTAL	
		# of Species	% Cover	# of Species	% of Cover	# of Species	% Cover	# of Species	%Cover
1	1.6 km SW	3	57	10	76	18	126	31	259
2	10 km NE	2	12	7	29	21	104	30	145
3	16 km NE	2	12	11	76	24	161	37	249
4	19 km NE	1	26	7	119	12	59	20	204
5	26 km NE	5	76	8	70	19	94	32	240
6	30 km NE	4	68	10	66	15	141	29	275
7	35 km NE	7	71	12	48	20	133	39	253
8	40 km NE	5	86	9	73	16	82	30	241
* 9	45 km NE	4	35	7	101	21	85	32	221
10	56 km NE	4	102	6	35	17	47	27	184

* 12 Grids examined at this location.

Table 10:

CONCENTRATIONS OF IRON, ARSENIC AND SULPHUR
IN VEGETATION AND SOIL SAMPLES COLLECTED IN THE WAWA AREA DURING 1975

	White Birch			Soil		
Plot No.	Fe (ppm)	As (ppm)	To S (%)	Fe (%)	As (ppm)	To S (%)
1 - July	973	6.2	0.11	2.88	157.0	0.08
Aug.	1533	35.2	0.66	2.03	27.0	0.07
2 - July	1117	21.8	0.43	0.26	34.3	0.11
Aug.	717	15.6	0.64	2.16	70.3	0.07
3 - July	366	10.1	0.40	3.06	80.7	0.06
Aug.	450	11.1	0.48	0.88	6.6	0.04
4 - July	297	8.4	0.38	1.20	15.2	0.12
Aug.	313	7.4	0.36	0.51	2.2	0.06
5 - July	285	5.9	0.25	0.36	3.9	0.16
Aug.	236	5.5	0.28	2.47	22.4	0.07
6 - July	169	3.4	0.19	1.13	10.7	0.06
Aug.	357	5.8	0.31	1.11	2.4	0.06
7 - July	227	4.1	0.23	2.23	5.4	0.05
Aug.	260	4.8	0.23	0.72	2.8	0.04
8 - July	264	3.9	0.17	0.05	7.9	0.03
Aug.	270	1.2	0.10	0.93	2.3	0.05
9 - July	234	1.0	0.10	0.71	1.6	0.03
Aug.	83	1.7	0.12	0.05	0.3	0.04
10 - July	62	0.04	0.09	0.04	0.3	0.02
Aug.	*70	--	--	--	0.3	--

* Based on One Sample

Table 11:

CONCENTRATIONS OF IRON IN SOIL AND WHITE BIRCH LEAVES COLLECTED IN THE WAWA AREA 1971-75

Plot No.	Location in Relation To Sinter Plant	Soil (%)					Vegetation(ppm)				
		1971	1972	1973	1974	1975	1971	1972	1973	1974	1975
1	1.6 km SW	-	-	-	-	2.46	-	-	-	-	1253
2	10 km NE	-	-	-	2.49	1.21	-	-	-	813	917
3	16 km NE	2.83	1.24	1.06	1.91	1.97	325	184	407	1133	408
4	19 km NE	3.52	2.06	0.94	1.94	0.86	155	129	178	679	305
5	26 km NE	0.37	0.65	2.20	0.45	1.41	115	92	174	269	260
6	30 km NE	1.83	1.65	1.92	1.36	1.12	120	96	150	287	263
7	35 km NE	2.39	1.35	1.20	1.73	1.48	96	78	111	157	244
8	40 km NE	1.27	1.49	0.59	*1.33	0.51	104	94	88	450	267
9	45 km NE(Control)	0.75	0.67	0.56	0.62	0.38	81	68	60	187	158
10	56 km NW(Control)	0.10	0.32	-	0.46	0.04**	77	73	78	111	66

* Based on two samples

**Based on the average of July samples only

Table 12:

CONCENTRATIONS OF ARSENIC IN SOIL AND WHITE BIRCH LEAVES COLLECTED IN THE WAWA AREA 1971-75

Plot No.	Location in Relation To Sinter Plant	Soil (%)					Vegetation(ppm)				
		1971	1972	1973	1974	1975	1971	1972	1973	1974	1975
1	1.6 km SW	-	-	-	-	92.0	-	-	-	-	21.2
2	10 km NE	-	-	-	2.81	52.3	-	-	-	28.1	18.7
3	16 km NE	56.5	48.4	53.0	63.8	43.6	9.0	5.4	9.3	17.0	10.6
4	19 km NE	24.9	20.5	13.0	13.8	8.7	6.2	5.7	8.6	8.6	7.9
5	26 km NE	6.5	6.9	2.1	8.5	13.1	3.1	3.5	4.2	3.7	5.7
6	30 km NE	72.6	16.2	21.0	21.0	6.6	3.8	2.8	8.4	2.2	4.6
7	35 km NE	8.4	8.2	20.0	6.4	4.1	3.0	1.3	4.0	*2.8	4.4
8	40 km NE	6.9	11.0	4.0	17.2	5.1	2.9	2.2	2.7	4.1	2.6
9	45 km NE(Control)	4.9	3.2	1.9	1.7	0.9	1.2	1.2	0.7	*0.8	1.4
10	56 km NW(Control)	2.0	4.1	0.4	0.8	*0.03	1.0	0.6	0.4	**0.9	**0.04

*Based on two analysis.

**Based on the average of July samples only.

Table 13: CONCENTRATIONS OF TOTAL SULPHUR IN SOIL AND WHITE BIRCH LEAVES COLLECTED IN THE WAWA AREA 1971-75

Plot No.	Location in Relation To Sinter Plant	Soil (%)					Vegetation(ppm)				
		1971	1972	1973	1974	1975	1971	1972	1973	1974	1975
1	1.6 km SW	-	-	-	-	0.08	-	-	-	-	0.38
2	10 km NE	-	-	-	.04	0.08	-	-	-	.48	0.54
3	16 km NE	.03	.03	.04	.05	0.05	.49	.41	.44	.58	0.44
4	19 km NE	.06	.03	.06	.04	0.09	.34	.43	.32	.46	0.37
5	26 km NE	.02	.03	.04	.04	0.12	.28	.33	.27	.30	0.26
6	30 km NE	.02	.02	.04	.03	0.06	.32	.33	.31	.30	0.25
7	35 km NE	.02	.03	.07	.03	0.04	.31	.26	.27	.27	0.23
8	40 km NE	.02	.03	.02	.03	0.04	.26	.28	.22	.29	0.09
9	45 km NE(Control)	.02	.02	.03	.02	0.04	.17	.23	.18	.14	0.11
10	56 km NW(Control)	.01	.02	.02	.02	*0.02	.19	.24	.16	.17	*0.09

*Based on the average of July samples only

Table 14:

ARSENIC CONCENTRATIONS IN PARTS PER MILLION
IN SOIL SAMPLES COLLECTED IN THE WAWA AREA
DURING 1975 (BASED ON THE AVERAGE OF 3 SAMPLES)

Location	Distance and Direction From Sinter Plant	Depth of Sample 0-5 cm	5-10 cm	10-15 cm
Dubreuil Rd. (1) *	45 km NNE	2.8	1.1	0.9
Beck School Wawa (2)	2.2 km SE	14.4	2.7	4.1
Hawk Junction (31)	21.3 km E	3.8	2.1	2.0
Centennial Park (4)	1.74 km SSE	35.0	5.1	8.2
Mission Road (5)	8.0 km SSW	12.3	4.0	3.5
Michipicoten Harbour (6)	9.0 km SW	10.1	3.5	2.6
Government Road (7)	0.5 km SE	728.0	75.4	15.2
Site 7 (8)	1.1 km NE		DATA INVALID	
Site 6 (9)	2.2 km NE	487.3	97.5	86.1
Site 5 (10)	4.2 km NE	98.8	18.0	20.0
Site 4 (11)	6.3 km NE	199.6	83.0	80.9
Site 3 (12)	7.7 km NE	160.4	71.8	15.4
Site 2 (13)	10.8 km NE	45.3	13.2	3.0
Site 1 (14)	13.8 km NE	47.7	9.3	6.1
Parks Lake (15)	16.0 km NE	60.6	36.3	13.8
Finger Lake (16)	19.0 km NE	15.9	10.0	9.6
Perry Lake (17)	26.0 km NE	7.1	2.9	3.3
Garbe Lake (18)	30.0 km NE	10.6	5.2	6.0
Goudreau (19)	35.0 km NE	11.0	8.6	6.7
Troupe Lake (20)	40.0 km NE	6.7	2.9	2.0
Lucy Pit (21)	12.0 km ENE	23.8	15.6	12.6
Wawa Park (22)	1.6 km SE	38.2	8.8	6.7
Highway # 17 (23)	1.6 km SW	544.0	28.8	8.3
Obatanga Park (24)	56.0 km NW	0.4	0.3	0.3

* - Number corresponds to site number in Figure 7.

Table 15: SUMMARY OF HIGH VOLUME FILTER ANALYSIS FOR WAWA DURING '75

Date (1975)	Total Loading (ug/m^3)	As (ug/m^3)	Fe (ug/m^3)	Pb (ug/m^3)	Zn (ug/m^3)
June 26	99	.011	5.85	.24	.16
June 29	262	.015	10.76	.30	.14
July 8	395	.045	17.26	.06	.11
July 11	110	.007	6.94	.13	.10
July 14	199	.012	9.75	.12	.09
July 17	392	.019	14.59	.45	.20
July 20	37	.003	2.16	ND	.08
July 23	63	.035	6.76	.49	.12
July 26	43	.004	1.39	.24	ND
July 29	100	.004	4.10	.31	.12
August 1	167	.012	6.09	.67	.12
August 4	79	.005	4.32	.25	ND
August 7	92	.005	5.25	.45	ND
August 10	93	.007	4.73	.30	ND
August 13	149	.008	5.37	.33	ND
August 16	180	.014	6.72	.19	.25
August 19	40	.006	3.29	.34	.18
August 22	65	.040	9.69	.38	ND
August 25	48	.004	2.11	ND	ND
August 28	107	.014	5.03	.38	ND
August 31	122	.053	14.25	.49	ND
September 3	34	.003	1.66	.20	ND
September 12	63	.210	12.60	.20	ND
September 15	51	.004	1.61	.28	ND
September 18	79	.005	3.08	.74	ND
September 27	104	.104	14.70	.69	ND
September 30	56	-	2.01	.22	ND
October 3	98	-	16.06	.40	ND
October 6	45	-	5.22	.52	ND
October 9	63	-	4.46	.42	ND
October 15	10	-	1.58	.23	ND

O.M.E. Criteria for Suspended Particulates:

- 24 hr: 120 ug/m^3
- 1 year: 60 ug/m^3 (Geometric Mean)

Table 16: CONCENTRATIONS OF VARIOUS CHEMICAL ELEMENTS IN FRESH SNOW SAMPLES COLLECTED IN THE WAWA AREA DURING JANUARY, 1975

Location in Relation To Source	Fe (ppm)	As (ppb)	Na (ppm)	Cl (ppm)	SO_4 (ppm)	Ca (ppm)	pH
8.0 km Northeast	1.50	7	0.10	0.34	1.0	0.3	4.20
12.0 km Northeast	0.89	5	0.25	0.82	2.0	0.3	4.40
16.0 km Northeast	0.65	5	0.10	0.64	1.0	0.2	4.20
18.0 km Northeast	0.60	ND	0.15	0.40	1.0	0.1	4.45
19.0 km Northeast	0.38	ND	0.05	0.24	1.0	0.1	4.40
26.0 km Northeast	0.62	ND	0.20	0.40	1.0	0.1	4.20
30.0 km Northeast	0.19	ND	0.10	0.24	1.0	0.1	4.35
40.0 km Northeast	0.13	ND	0.10	0.30	ND	0.1	4.35
42.0 km Northeast	0.08	8	0.10	0.34	ND	0.1	4.30
43.0 km Northeast	0.25	6	0.15	0.20	1.0	0.1	4.30
58.0 km Northeast	0.05	ND	0.10	1.10	1.0	0.2	4.30
0.5 km East	11.00	32	0.60	1.70	6.0	2.8	6.01
1.6 km East	5.00	18	0.80	1.90	1.0	1.4	5.20
1.6 km Southwest	88.00	230	4.30	7.60	16.0	12.0	5.20
4.8 km Southwest	4.80	21	0.30	0.70	4.0	0.9	4.90
9.5 km Southwest	5.00	21	2.10	2.30	5.0	1.0	4.85
0.9 km Southeast	4.10	17	0.60	1.20	3.0	1.0	5.25
56.0 km Northwest	1.60	9	0.75	1.70	17.0	1.2	4.50
CONTROL	0.13	7	0.12	0.55	1.0	1.0	4.30

* Not detectable

** Control Site

Table 17: LOCATIONS OF WAWA AREA SNOW SAMPLING SITES IN RELATION TO THE ALGOMA ORE DIVISION SINTER PLANT-1975

	Location	Distance and Direction from Source
1.	Arliss Lake	8.0 km Northeast
2.	Lucy Pit	12.0 km Northeast
3.	Parks Lake	16.0 km Northeast
4.	Hawk Junction	16.0 km Northeast
5.	Finger Lake	19.0 km Nortneast
6.	Perry Lake	26.0 km Northeast
7.	Garbe Lake	30.0 km Northeast
8.	Troupe Lake	40.0 km Northeast
9.	Goudreau Lake	42.0 km Northeast
10.	Cawdron Lake	43.0 km Northeast
11.	Wabatonguishi Lake	58.0 km Northeast
12.	Government Rd., Wawa	0.5 km East
13.	Wawa Lake	1.6 km East
14.	Highway #17	1.6 km Southwest
15.	Mission Rd.	4.8 km Southwest
16.	Michipicoten Harbour	6.6 km Southwest
17.	Queen's Park, Wawa	0.9 km Southeast
18.	Obatanga Provincial Park	56.0 km Northwest

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